VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXLV.—JANUARY, 1881.—VOL. XXIV.

IMPROVEMENT OF RIVERS AND HARBORS ON THE ATLANTIC COAST OF THE SOUTHERN STATES.

Abstracts of Reports of General Q. A. GILLMORE.*

I.

The character and magnitude of the works in progress along our Southern Atlantic border attract attention only when the brief summary of the year's work is published, and then excite a momentary interest, only, in the many who do not know that an engineering problem of great importance is in process of solution.

To aid, by artificial construction, in the establishment of a way permanently open to navigation, and free from the danger of accumulations of silt or sand, is the end sought. This requires, first of all, an intimate knowledge of the character and habits of all currents in the neighborhood, so that by properly directing them, they may aid, or at least shall not obstruct the end in view.

There is a widespread popular notion that the method of such improvement by *jetties* was first successfully applied at the mouth of the Mississippi, whereas such means have been employed, with more or less success, for nearly a century. The improvements at the mouth of the Danube, at Currachee in India, and the harbor of Dublin, are of this kind, and, under the name of piers or sea-walls, they are found in many important commercial ports.

The skill of the engineer is exercised when applying such a method, in adapting it to the special conditions which confront him in each case. A general plan of procedure, when a harbor is to be constructed at the mouth of a river, is to build piers or jetties out into the widened mouth of the river in such way as to continue the current of the stream, making the space between them as wide as the throat of the harbor or the waterway of the river; also to carry the jetties up to or above the surface of the water. One effect of this plan is to move the throat of the harbor to the outer extremity of the works, and to establish there the same conditions, so far as the deposit of a bar is concerned, as formerly existed nearer the mouth of the river.

In Charleston harbor, where the more important of the works covered by the report are in progress, Gen. Gillmore proposes to construct the jetties lower than usual, keeping them entirely below low water; also to make the width enclosed between them less than one-half the width of the natural throat of the harbor. The tide will therefore ebb and flow over the tops of the jetties. The

*Annual Report upon the Improvement of the Rivers and Harbors on the Coast of South Carolina, Georgia, and the Atlantic Coast of Florida, in charge of Q. A. Gillmore, Lieut.-Col. of Engineers, and Bvt. Maj.-General, U. S. A.

object sought is to cut a narrow and deep channel through the bar without moving the bar.

"The bar which stretches bow-shaped across the entrance into Charleston Harbor, from Sullivan's Island on the north to Folly Island on the south side, has not varied much in either location, general direction, or magnitude within the period covered by any trustworthy knowledge which we possess on the subject.

"In the year 1852 a commission, composed of Prof. A. D. Bache, Superintendent of the United States Coast Survey; Lieutenants J. N. Maffitt, M. F. Maury, and C. H. Davis, United States Navy; and Lieut. J. D. Kurtz, United States Army, in a report on Charleston Harbor and Bar, made with special reference to works of permanent improvement, stated that a comparison of the chart of 1780, published in Des Barrés' Atlantic Neptune, with those of 1821, 1825, and 1851–'52, 'shows that according to the earliest records the bar of Charleston has varied comparatively but little in extent, direction, or in distance from the mouth of the harbor.'

"Measured along its crest, or line of least depths, the bar is ten miles in length, its north end on Sullivan's Island being close up to the entrance or throat of the harbor, while its south end, resting on Folly Island, is six miles distant therefrom. Its average width between the 18 foot curves is about $1\frac{3}{4}$ miles.

"In many places the highest points of the bar are only 3 to 4 feet below the level of mean low-water, although the average depths along the crest are considerably greater.

"The main central body of the bar, lying near due north and south, is nearly straight for a length of over five miles, has its crest parallel to the main shore south of the entrance and at a mean distance of about two miles from it, and is not at the present time, and, so far as we know, never has been traversed by practicable ship channels.

"The northern and southern extremities of the bar are formed by rather sharp curves, which connect the straight portion already mentioned with the shore above and below the harbor.

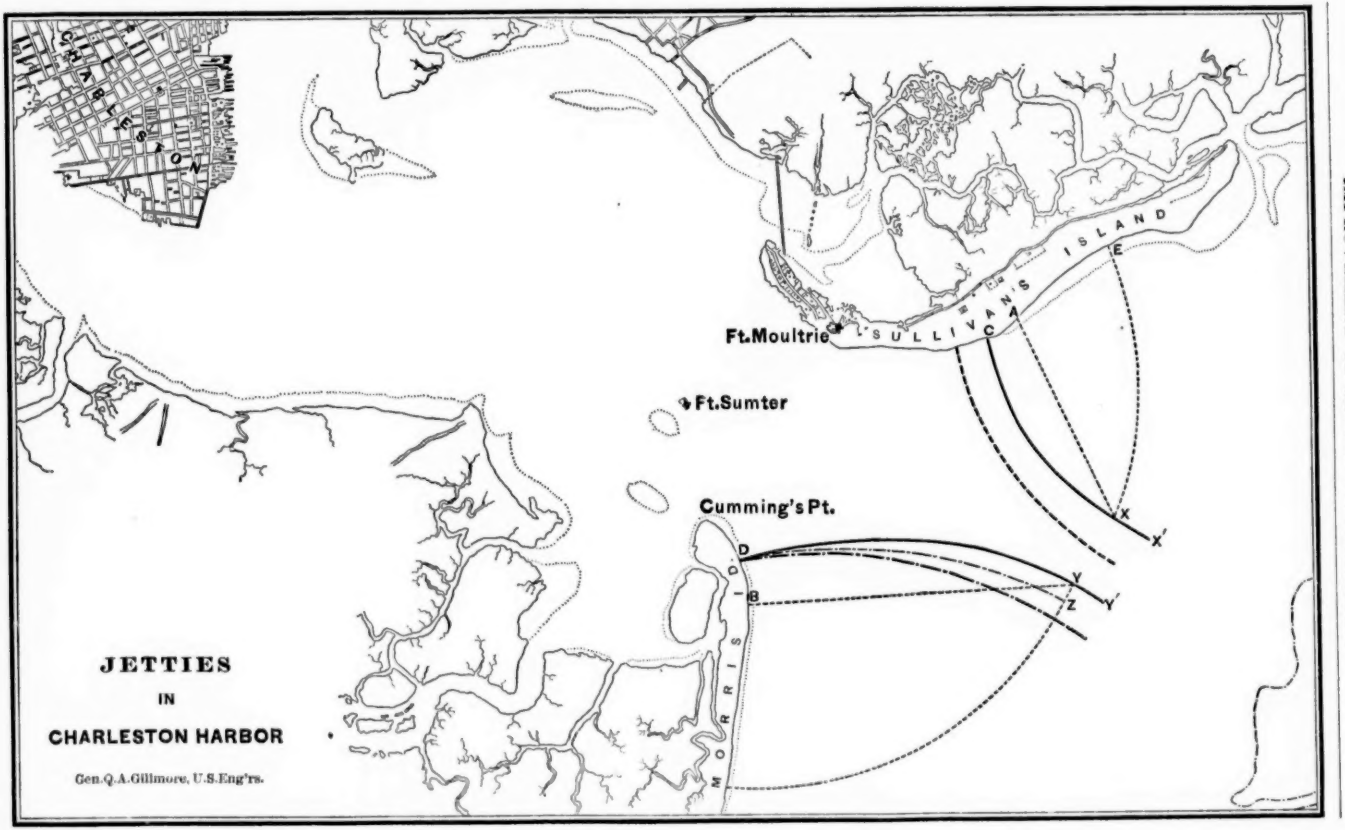
"So far as we can now ascertain there appear never to have been less than four nor more than six ship channels across the bar at any one time. The greatest depth of water has sometimes been found in one channel and sometimes in another, being rarely less than 12 feet or more than $13\frac{1}{2}$ feet at mean low tide.

"The channels, whether four or more, have always existed in two groups or clusters, one in the northern and the other in the southern curved portion of the bar, and there has always been a deep and broad anchorage inside the straight reach of the bar abreast of Morris Island.

"This anchorage, sometimes called the 'main channel' and sometimes the 'outer harbor,' varies in width from one-third to two-thirds of a mile between the 18 foot curves, and in maximum low-water depths from 20 to 45 feet. The direction of its central line is about north and south, and its length from the throat of the harbor between Morris and Sullivan's Islands to its southern terminus, where it spreads out in various channels and shoals in crossing the bar, is fully five miles. At the extremities of this outer harbor or basin, several miles apart, are found the two groups of channels already mentioned, the most northerly group being directly in front of the gorge of the harbor.

"The bar is essentially a drift-and-wave bar, produced in part by the upheaving action of the waves when they approach the shore, and are converted by break ing into waves of translation, and in part by drift material carried along the coast by surf currents, especially by those produced by northeast storms. The peculiar location of the bar, largely to the southward of the gorge of the harbor, and the conditions under which a very large proportion of the ebb-flow is diverted from its most direct path, and forced to skirt the main coast for several miles before it can find a passage to the sea, indicate the controlling power of these storms.

"The material composing the surface of the bar closely resembles that usually found on the sea shore between high and low water in that section of the country, being shells and fragments of shells, or silicious sand, or a mixture of them all. It is easily thrown into suspension by waves, and is moved by a moderate current.


CHARLESTON
Ft.Moultrie
SULLIVANS ISLAND
Ft.Sumter
Cumming's Pt.
MORRIS
A
B
C
D
E
X
X'
Y
Y'
Z
JETTIES
IN
CHARLESTON HARBOR
Gen.Q.A.Gillmore, U.S.Eng'rs.

"On the north end of the bar five borings were made in order to determine the character of the substrata.

"All the channels which traverse the bar are, and, so far as we know, always have been, ebb-tide channels, produced and maintained by the scour of the ebb-current, except Beach (formerly Maffitt's) Channel, the most northerly of them all, which lies close to Sullivan's Island. This is a flood-tide channel, possessing the usual characteristic of such channels, that their least depths are always found near their inner ends, and, therefore, in comparatively quiet water. Another distinguishing feature of such channels is that from the cross section of shoalest soundings inward, toward the harbor, the descent into deep water is sharp and sudden, while outward, toward the ocean, it is gradual and gentle."

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"It having been determined to begin the works by laying so much of the apron foundation of the North or Sullivan's Island jetty as the appropriation made June, 1878, would cover, a careful survey for location was made of a strip or belt of the bar about 800 yards wide and 5,000 yards long, extending from Sullivan's Island in a southeasterly direction, so located as to embrace the whole of the north jetty, even should it be deemed expedient, in view of the additional information recently obtained, to add largely to its length, and make very considerable changes in its location.

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"The following extract from the specifications which formed part of the contract under which the work of 1878 was executed, describes in general terms the apron of the north jetty, according to the original plan:

"'A design for the apron has been prepared in this office, which is deemed suitable for the purpose. It consists essentially of a platform of round logs from 11 to 12 inches in diameter, placed and held close together, side by side, at right angles to the axis of the jetty. The logs are to be as straight as can be procured, and those of about the same size must be selected to go together. This log platform is to be overlaid by a compact layer of stout brush to a depth of 12 to 14 inches, projecting from 10 to 12 feet beyond the ends of the logs on either side, the projecting portion being closely confined and bound together so as to form a kind of mattress. As much brush should be used as the logs will bear up and float. Upon this wooden substructure, which will be at least 2 feet thick, good soundstone of random sizes and of compact form, but none weighing less than 30 pounds, will be placed as compactly as possible. The depth of this bed of riprap stone will be $2\frac{1}{2}$ feet for all that portion of the work that constituted a part of the stone superstructure and lies within the side slopes of the jetty, while a depth of only 1 to $1\frac{1}{2}$ feet will be required upon that portion on either side which projects as a mattress beyond the foot of the side slopes.

"'The total length of the north jetty, according to the original plan, is about 8,840 feet. This may be increased hereafter.

"'The width of the log platform at any point will be regarded as the bottom width of the jetty at that point. As the apron progresses the pre-arranged widths may require a slight increase in consequence of scour in advance of the work. The greatest bottom width of platform will be about 92 feet, and the least will not be less than 33 feet. The average bottom width may be a little greater or less than 52 feet, but for the purpose of bidders will be taken at 52 feet.'

"In November the contractors requested a modification of the specifications, with respect to the method of making the mattresses, constituting the bottom portion of the apron. They proposed to make the log platform 10 feet wider than the contract required, to omit the joints in the logs, and restrict the projection of the brush beyond the ends of the logs to 4 feet.

"In forwarding this proposition for the action of the Chief of Engineers, it was stipulated, with the contractors' written consent, that the projecting brush was to be close and massive, although not formed into a mattress as in the original plan, that the quantity of riprap stone used in the apron was to be the same as specified in the contract, and that the cost of the work to the United States was not to be increased; also, that none of the riprap stone was to be placed upon the projecting brush, all of it being

distributed above and over the area occupied by the log platform.

"These proposed changes in the details of the plan were approved by the Chief of Engineers, under date November 13, 1878.

"A cross-section of the apron, according to the design as amended, is shown in Fig. 2.

"The comparatively low bottom velocities of the ebb current observed on the seaward slope of the bar seemed to point to the necessity of giving the jetties greater length than that contemplated in the original project. It was thought best also to adopt a longer radius for the curved portions of the north jetty, and to carry the point of tangency between it and the straight portion farther to seaward.

"It was determined to retain the original point of departure from the line of ordinary high water on Sullivan's Island, and to carry out the jetty for a length of 8,840 feet, on an arc of a circle described with a radius of 2½ miles, so located that a straight tangent at the sea-end of the arc would have a direction about east 32 degrees south.

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"The contractors, anticipating great difficulty in laying their work upon a shoal lying in the line of the north jetty, known as Drunken Dick Shoal, which is covered with breakers a great portion of the time, requested, under date April 21, 1879, such a change in the location of the line of the jetty as would in effect divert it to the westward, thereby escaping a portion of the shoalest water, and diminishing the quantity of work to be put down in the breakers.

"The work from the beginning had been laid upon straight ranges, or chords of 400 feet in length, and not upon the circular arc of 2½ miles radius. By the change desired the line of the work, after completing the eighth chord, 3,200 feet from ordinary high-water mark on the shore, would continue on the straight prolongation of that chord for a distance of about 3,000 feet, or until Drunken Dick Shoal was crossed. This change of direction was approved for a length of 2,000 feet beyond the eighth chord, leaving it to be determined, when that limit shall have been reached, whether the work shall be continued on the straight line, or on an arc of 2½ miles radius parallel to the original arc, or otherwise.

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"The width of the log platform which forms the base of the structure varies from 43 feet to 66 feet. These widths include the 10 feet added in modifying the design as already noted, and, therefore, exceed by that much the widths on which payments have been made.

"The riprap stone is required by the contract to be sound stone of random sizes, but none weighing less than 30 pounds. The maximum sizes were not specified, either by weight or dimensions, and the contractors assumed and insisted on the right to exclude heavy stones. The largest pieces are such as one man can pick up and throw overboard from the scows used in conveying the stone to the jetty, while the smaller sizes run somewhat under the prescribed limit of 30 pounds. As these latter, however, in great measure go to fill up the interstices between the large pieces, thus increasing the weight of the mass without materially adding to its bulk or cost, no objection has been made to their use to a moderate extent.

"The frequent inspections that have been made do not show that any of the stone has yet been carried off the apron by the force of the waves, and perhaps no apprehension need be entertained of serious disturbance from this cause to any of the work already laid, unless it be on that portion put down in June, 1879, on the inner slope of Drunken Dick Shoal, where the depth at mean low-tide does not exceed 8 to 8½ feet. It seems hardly safe to assume, however, that stone of such small sizes will continuously withstand the force of the waves on the crest and exterior slope of the bar. Not that there is likely to be any sudden movement of large masses, but that the waves produced by the prevailing heavy storms, those from the northeast, will carry the stones gradually, a few only, and for short distances at any one time, from the inner slope of the jetty to its crest, and thence over to the western slope. Large stones will have to be used for the upper portions of the work, and some device may have to be resorted to for holding them in place.

"The design of the apron is such that the log platform which forms its base would be exposed to the ravages of the teredo unless covered with sand or other material placed upon the ends of the logs, or accumulated there by the action of the currents, or by the settlement of the structure.

"An examination made on the 24th of June shows that for a length of about 1,450 feet from the high-water mark on Sullivan's Island, comprising all the work laid before the 4th of February, the apron is so well embedded in the sand as to afford a complete protection to the wood.

"Most of the work laid in February, and all laid subsequent thereto, is more or less exposed, and directions were given near the end of June to cover the exposed wood with riprap stone.

"No settlement of the work has been detected on any part of the line."

As set forth in a former report, the plan is stated in these words:—

"It is proposed to construct two jetties, one springing from Morris Island and the other from Sullivan's Island, converging toward each other in such manner that their outer ends on the crest of the bar *shall be one-half to five-eighths of a mile apart.* The outer ends of the two jetties will rest respectively upon the shoals lying to the northward and southward of what is known as the north channel, that being the middle channel of the north group of three channels, and having its line of deepest water located, more nearly than either of the others, upon the prolongation of the axis of deep-water flow through the gorge of the harbor between Cumming's Point and Fort Moultrie.

"Assuming, for the purposes of discussion, the sea ends of the jetties to rest respectively at X and Y, it seems, in some measure, immaterial whether they be established upon straight lines, as shown at AX and BY, or upon curved lines; and if curved, whether the convexity be turned toward the central channel, as at CX and DY, or from it, as at EX and FY. In either case, if kept at the proper heights, they will produce an ebb-flow through the gap able to maintain a deep channel through the bar. Neither the straight jetties, however, nor, more especially, those with their convexity turned away from the channel, act as training-walls to guide the outflowing water. The curved jetties, convex toward each other, being less open to this objection, are the ones adopted in this project.

"The north jetty starts from a point on Sullivan's Island, 1,800 yards east of Bowman's jetty. The half next the shore is curved to a radius of about $1\frac{1}{2}$ miles, the outer half being very nearly a straight line. The total length of this jetty, from C to X, is 7,450 feet, and its general direction is southeast.

"The south jetty, having a total length of 11,650 feet, from D to Y, starts from Morris Island at a point about 650 yards from Cumming's Point, its general direction being east. The shore end is curved to a radius of about 3 miles for a little more than one-half its entire length, while the half next the sea is nearly straight, as in the case of the north jetty.

"The specified length of the jetties is taken for purposes of discussion. As will be seen hereafter, they would not be able to produce a channel of the requisite capacity through certain materials which may be encountered in the bar, although they would be expected to maintain such a channel if once established.

"The outer ends of the two jetties slightly converge toward each other as they approach the crest of the bar, and are intended to act as training-walls for a distance, in each case, quite equal to half its entire length. These portions lie in the direction of the flood-currents, and may be built to any height without obstructing the inflow. For fully one-fourth of their entire length the sea ends could be carried above the level of high-water, so as to be visible at all stages of the tide. The inner portions, crossing the Beach and main channels, respectively, might perhaps be kept low enough to allow the smaller classes of vessels to pass over them.

"One characteristic feature of the design—that of low jetties—is intended to maintain the bar in its present general location, with such moderate increase of magnitude as may be expected to result from concentrating, upon a gap one-half to five-eighths of a mile in width, a portion of the water which is now dispersed over a width of 10 miles.

"The complete success of the works is believed to depend on three important conditions, which they are expected in a great measure to satisfy, and which have been kept in view in preparing the design, viz.:

"1. *They should not impede the inflow to such degree as to prevent the tidal basin being filled, as now, at every influx of the tidal wave.*

"To this end the inner half of each jetty, more especially its central portion, located in deep water across the thread of the current, is kept several feet below the water. The outer half, being nearly parallel to the direction of the flow, is built higher, and the sea end, for a distance of several hundred feet, may be carried high enough to be visible at all stages of the tide.

"2. *They should control the outflow to such degree, and in such manner, that a channel of the required depth will be maintained through the bar.*

"To this end, although a large portion of the *surface flow* will spread out over the tops of the jetties and thence over the bar, the *central flow*, throughout the entire depth along the axial line of the gorge between Sullivan's and Morris Islands, is aided in its natural tendency to reach the sea along the prolongation of that line by the opening left for it between the jetties. The *bottom flow* through the gorge of the harbor is deflected on converging lines by the jetties, and is, therefore, forced in a measure to concentrate itself in, and flow out through, the gap between them. The outer half of each jetty, and the adjacent portion of the shore end act as a training-wall for this flow.

"3. *They should not, to any considerable extent, cause a movement seaward of the main body of the bar; that is, the general position of the bar should be independent of the effects produced between and beyond the heads of the jetties.*

"It is believed that this condition will be secured by making the shore ends of the jetties low for at least one-half their length, or throughout those portions which cross the thread of the current in deep water, so as to allow the tide to ebb and flow somewhat freely over them. The effect of high jetties, with a correspondingly wide gap between them to allow a full influx of the tide, would tend to transfer the gorge of the harbor from its present position to the sea ends of the jetties and move the shore line out to that point, by causing a filling in of the exterior angles between the jetties and the shore. After reaching this stage, a drift-and-wave bar would probably be found to the seaward of the present bar, in front of the jetties, rendering it necessary to extend them, in order to cut a passage through it.

"It seems essential, therefore, that the agencies which maintain the present bar should remain in as full force as possible, consistent with the requisite concentration of outflow between the jetties.

"The probable effects will be that the bar will be raised somewhat throughout its entire length, the waves will break upon it more frequently than now, and considerable shoaling will, of course, take place in Beach Channel and in all the southern group of channels. But it is believed that the important condition of keeping the bar generally in its present position will be secured.

"The drift material carried along the coast by surf-currents, as well as the sand thrown up by the breakers on the north and south shoals, instead of lodging in and filling up the exterior angles between the jetties and the shore, as in the case of high jetties, will be disposed of in a harmless manner.

"For example, a heavy northeasterly storm, producing breakers along the north shoal and strong southerly surf-currents along the shores of Long and Sullivan's Islands, would put in motion a large quantity of material, a portion of which would be carried in by the flood-currents over the north jetty and through Beach Channel, coming to rest in the deep water of the main channel. It would next be taken up by the ebb-current and rolled out to sea between the jetties. Beyond the jetty-heads it would encounter the littoral ebb-current, moving to the southward with a velocity accelerated by the storm, by which it would be again carried in a southwesterly direction, until, finally, left to the action of the south breakers, it would be either deposited temporarily upon the south shoal, or carried still farther to the southward.

"The action of a southerly storm would be the reverse of this. In either

ase some drift-material would be carried by waves and surf-currents around the jetty heads, and would subside in the deep water between them, to be swept out by ensuing ebb-currents, and disposed of to the northward or southward, according to the direction of the storm.

"This movement of sand was referred to in my report on the improvement of the Fernandina Bar, submitted April 15, 1876, from which the following extract is made:

"'As a moderate assumption, a northeaster of three days' duration might be expected to lower the north shoal four inches within the area covered by the breakers. The greater part of the eroded material, amounting to upward of 516,000 cubic yards, would doubtless be distributed along the south shoal during the progress of the storm. If the waves should subside, or a southerly or southeasterly storm set in before the bar channel had returned to its normal condition, the material subsequently carried out would not reach the south shoal, but in the former case would remain near the outlet on the outer slope of the bar, and in the latter would be carried back by the waves to the north shoal. If as much as one-fourth of it remained in the bar channel, between the inner and outer 18-foot curves, a few severe storms, such as frequently occur within the period of a single month, would entirely destroy it, by filling it up to the level of the shoal on either side.

"'It would appear, therefore, that millions of cubic yards of the material composing the bar might be shifted back and forth from one side of the channel outlet to the other, during a single season, without causing injury to the channel by shoaling, and without producing any changes in the form and location of the bar itself that might not entirely escape the notice of the most careful surveyor. And yet this shifting of material, of which no evidence may be left behind, should enter as an important, if not a controlling, function in the project of the engineer, because the useful life of his works is more or less dependent thereon.'

"As no works can be expected to stop this movement of drift-material for any great length of time, they should, if practicable, accommodate themselves to it under conditions of a permanent character. Those proposed are designed to do this, by allowing the drift-sand to move from one part of the bar to the other, in much the same manner as now, never remaining in the jetty channel longer than a few tides, and never finding a resting-place anywhere that the next storm may not disturb."

From the forthcoming report we learn that:

"During the fiscal year just closed, the work of putting down the apron of the North jetty was continued, and the construction of the South jetty was begun.

"The foundation matters of the North jetty continued to be made after the modified design (see Fig. 2). Another modification in this contract was made August 19, 1879, under which a mattress was inserted as a hearting in the rip-rap superstructure of the apron, in order to get increased height by the use of a material less costly than stone.

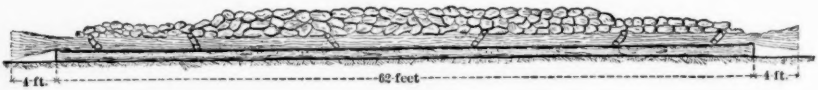


Fig. 2.

"This second mattress, which is in all essential features like the lower one, has a prescribed thickness of 18 inches in the finished jetty, and is paid for in the work at the rate of $5 per lineal foot of mat, fifty-four feet wide, equivalent to $1.66⅔ per cubic yard. When the bottom mattress has been sunk and loaded with stone to the depth of a few inches, as evenly distributed as possible, the second mattress is sunk in its place, and the balance of the 2½ feet layer of stone, required by contract on the apron, is placed upon it.

"The width of the second mattress is uniformly less, by 32 feet, than of the one at the bottom, in order that the rip-rap superstructure laid with flat slopes will cover it and protect the ends of the

logs from the ravages of the teredo. Less apprehension of injury from this cause is felt for the bottom mattress, for the reason that from its position, directly on the bottom, it is likely to become quickly covered with sand whenever there is any tendency to fill at all.

"When the apron of the North jetty had attained a length of about 5430 feet from the shore, in only 5 feet low water soundings on the inner slopes of Drunken Dick Shoal, work was suspended on account of rough water and breakers, and resumed on the seaward slope of the shoal, at a point on the amended curve of location, leaving a gap of 1647 feet to be filled in hereafter.

"If this shoal, which at present shows, on some portions of it at least, indications of considerable stability, shall continue to resist abrasion and wear, after the work on each side of it reaches the required height, there will be no special need of re-enforcing it, or of raising its surface artificially. If, on the other hand, it yields under increased currents, or wherever it does yield and wear away from any cause, increased depths will be the result, and the breakers will doubtless subside to such a degree that there will be no special difficulty in laying the work.

"During a spring tide of considerable range in the month of July, 1879, a large portion of the shoal was laid bare at low water, and part of a wreck which has doubtless been there for some years was discovered on it, indicating that the material of the shoal has considerable firmness and tenacity.

"So far as known, this precise locality has never been examined by boring.

"When work under the first contract was finished on the outer end of the jetty, the use of the second mattress, which is not adapted to the thin courses of the later contract, was also discontinued.

"The prosecution of work upon the North jetty since the 10th of May, and upon the South jetty since the 23rd of April, has been in conformity to a contract dated September 6, 1879.

"Under this new contract the engineer-in-charge has the power to regulate the height of the jetty by laying it in one or more courses, and the work can be prosecuted by extending the North jetty, and raising it higher at certain points, and by beginning the construction of the South jetty.

"Among the specifications of the contract for the work to be done this year is one for mooring chains of wrought iron, to be afterwards used in securing the top layers of stone on the finished jetty, against removal by the waves, will be attached to the logs of certain mattresses at intervals of 40 to 50 feet along the line of the jetty where most exposed to the force of the waves. The lower end of each chain terminating in a ring will be supported by a buoy, spar, tripod or otherwise, so that it will not become covered up with stone, and can be found at any time. The chains will be galvanized in the best manner.

"These galvanized mooring chains will be what is known as chain cables, and will be of such sizes, not less than 1 inch, nor more than $1\frac{1}{4}$ inches in diameter, and of such lengths, and attached to such mattresses, and at such distances from the sides thereof as the engineer-in-charge shall direct.

"A second course will probably be placed on some portions of both jetties before, or during the coming Autumn.

"It is not the present intention to give the base of the south jetty, during this fiscal year, its full width where it crosses the main ship channel in about 40 feet low water soundings. It seems desirable that as great height as possible should be gained in this deep water with the funds now available, and the work will therefore be laid in two or more courses, the bottom one being about half the required width. It is possible that the sand will fill in so rapidly that the full width of base adapted to this great depth will not be needed. When the bottom course, rising to a height of about 2 feet 8 or 9 inches has ceased to accumulate sand, the second course will be laid, and after that perhaps a third course in some places.

"An inspection was made a few days before the close of the fiscal year, of the entire line of work on the north jetty. No settlement was detected in any portion of it, except in the deep water of Beach Channel, where for a length of 200 feet a subsidence seems to have taken place varying from 1 to $3\frac{1}{2}$ feet, the immediate cause of which has not been ascertained.

"On that portion between Drunken Dick Shoal and Sullivan's Island, the ends of the logs are reported to be well covered with sand, except when the low water depth does not exceed 8 feet. On former examinations the timber even in this shoal water was found to be covered. The cause to which its present exposure is to be attributed, cannot be positively stated.

"South of Drunken Dick Shoal the ends of most of the logs remain uncovered, and exposed to the ravages of the teredo.

"It is proposed to cover all the exposed timbers with rip-rap stone, and steps have been taken to procure it as soon as practicable.

"It is found that sand accumulates very slowly around the ends of the logs, on the south jetty. No settlement is reported there.

"A few months before the close of the fiscal year, I had an opportunity to examine the shore end of the north jetty, at an unusually low stage of water, and I found that the rip-rap stone, placed there 15 months before, had become so firmly cemented together with barnacles and other shell-fish accretions, as to render the mass remarkably dense and compact.

"It seems quite improbable that the stone, even on the most exposed part of the work beyond the bar, will ever be washed off or moved by the waves, if it can once be consolidated in this manner by the molluscan growth of a single summer.

"It may be hoped, therefore, that recourse to the mooring chains, for holding a line of large stones, linked together along the crest of the work, for which provision was made in the contract, will not be necessary.

"The work has not yet reached that stage when increased depths can be expected in the swash channel, which, occupying the proposed gap between the two jetties, is, nominally, the one to be improved.

"But it is neither expected nor desired that the improved channel will occupy the line of the present one. It is a crooked channel lying at an average distance of not less than 1,400 feet from the line selected for the North jetty. On the shoals lying between it and that jetty, however, a marked increase of depth, amounting to three feet, over considerable areas, has taken place during the past year, which is to be attributed to the direct action of the jetty. The changes were more rapid as the jetty advanced. The effect has been to move the inner end of the swash channel northward. It may be expedient to assist, by dredging, this developed tendency to scour along the line of the proposed channel, when the time for such auxiliary work shall have arrived.

"During the month of June, 1879, arrangements were made to cover the exposed logs, north of Drunken Dick shoal, with ballast stone and brick-bats; but the sand eventually collected along the margin of the work sufficiently to afford the requisite protection. Only 18 cubic yards of brick and stone were placed on the work under this agreement.

"During the present fiscal year, it is expected that both jetties will be extended, and, in some places, raised to a higher level under the existing contract, and others to be entered into hereafter, by methods the same, or substantially the same, as those hitherto followed; and, if deemed advantageous, some dredging will be done by the United States dredge steamer 'Henry Burden,' along the line of the proposed channel.'

Coal in India.—Theodore W. H. Hughes begins a paper on the coal fields of India by saying: "It will doubtless surprise many to learn that both in the superficial extent of its coal measures and associated rocks, and in the actual amount of its coal, India is surpassed by few countries, and that with respect to the size of some of the seams it stands pre-eminent in the history of mining." Even the United States cannot boast of seams 100 feet, 120 feet and 160 feet thick, like some that occur in Bengal. He calculates that the coal fields of India cover 35,000 square miles, and according to estimates drawn up by Dr. Oldman there cannot be less than 20,000,000,000 tons of coal in the Empire. Much of the material, however, is of an inferior quality and fit only for very rough use. —*L'Ingen. Univ.*

THE VALUE OF THE STUDY OF THE MECHANICAL THEORY OF HEAT.

By ALFRED R. WOLFF, M. E.

A Paper read before the American Society of Mechanical Engineers, November 5th, 1880.

I

In presenting a few remarks on the Value of the Study of the Mechanical Theory of Heat, I am imbued with the knowledge of two facts: of the importance and value of the study on the one hand, and of, in general, a lack of proper appreciation among engineers of this point on the other. There are doubtless few among educated engineers who would not admit that the acquisition of any form of knowledge is of value, not only as a training of the mind but as an addition to our understanding of the laws and working of the universe and mankind; few who would deny that the study of literature, of social or politico-economic sciences would be of benefit to them, though of limited influence in the practice of their profession.

From personal experience, as well as from the experience of others, I am led to believe that engineers, as a class, look upon the knowledge of the mechanical theory of heat not much unlike than that of the department of "belles-lettres," as possibly adding to refinement, to a broader view of things in general, to a fair drilling of the mind, but of no practical or only slight practical value in the ordinary, or even extraordinary, exercise of their profession. I am not prepared to say that were the grounds above enumerated the only ones upon which the study could be urged, that a strong argument in favor of its more general introduction could not justly be maintained; but this question does not arise since the more general introduction of the science can be presented to the engineer on the ground of direct, practical utility, for the purposes of correctly appreciating and increasing the efficiency of a large department of his profession, that department which treats of the transformation of the latent or active forces or powers of nature in a form suitable for application as motive power for utilization in machinery designed to do the desired special work, or, in other words, to that department which relates to the generation of the working fluid or motive power, and the work performed by the medium of such fluids in prime movers. It is on this ground that I would urge the more general acquisition of the science of thermo-dynamics, and to insure conciseness as well as a ready conception of my views, I will only briefly outline the thoughts, giving as it were their direction, and leave it to you to give them force, that is, to develop them more fully as your own understanding and experience will best suggest.

Thermo-dynamics or the Mechanical Theory of Heat is, as the name implies, the science of the laws of heat considered as a form of energy. It is based upon two great, general laws, the one that all forms of energy are mutually convertible in certain exact, invariable equivalents, the other that the quantity of energy in a homogeneous substance is equal to the sum of the energy of its component parts, and that equal parts of a homogeneous substance when undergoing a change of, or exerting, energy undergo like changes, and exert like effects. The application of these two fundamental laws of energetics to heat constitute the determination of the two general laws of thermo-dynamics, which are the basis of the whole science, and of which the science is in fact but an extension and application to forms of heat energy, latent or active, met with in nature and valuable in practice. For after all what is theory but practice reduced to a connected system of laws or principles. Without facts, without phenomena, in short, without practice as a foundation, how could theory ever be conceived or established? In ordinary discussion but little attention is paid to the distinction between theory and hypothesis, and nothing has proved more dis-

astrous to a general appreciation of theory than the repeated misuse of the term. Theory is based on facts, hypothesis on speculation, hypothesis changes to theory when speculation changes to facts. The two special laws of thermo-dynamics, upon which the whole science is elaborated, to which we refer are: that heat is convertible to other forms of energy in the relation of what is known as Joule's equivalent, that is, that one thermal unit (the quantity of heat required to raise one pound of water at 39.4° Fahr., one degree in temperature) is equal to the energy required to raise 772 lbs. 1 foot, or that 772 lbs. falling 1 foot will develop sufficient heat to raise 1 lb. of water at its greatest density 1 degree. The second is that if the total actual heat of a homogeneous and uniformly hot body undergo a change or exert energy, equal parts of the body will undergo equal changes and exert like effects, the sum of the effects of the component parts being equal to the total effect. This law is more popularly identified in the form of Carnot's theorem, a special application to heat engines, that $q-q_1$ or $\frac{T-T_1}{T}$, is the limit of efficiency of such engines, and that the test of a perfect engine is its reversibility. q and T represent respectively the quantity of heat and absolute temperature of the (any) fluid when leaving the generator, and q_1 and T_1, respectively, the quantity of heat and absolute temperature of the fluid when given off to the refrigerator; $q-q_1$ when entirely converted into useful work causing the engine to become theoretically perfect.

The above outlines the foundation and framework of a great science. It is strong and simple, and in its strength and simplicity beautiful. The structure and superstructure are equally strong, equally beautiful, but not, however, equally simple. If this were the case there would be little need of the presentation of papers of this kind, for the great value of the science would be universally acknowledged. It is a common experience that the mass of mankind primarily pronounce that which is difficult to attain as not worthy of attainment, primarily too often look upon those who have mastered the difficult with scornful or doubting eye, until the achievement of the difficulty by the few has brought forward such valuable results, such striking truths, so influences the ordinary experiences and our conception of facts in nature or in our professions, that the worthiness and value of the attainment can no longer be denied and must be definitely accepted. That point has now undeniably been reached in thermo-dynamics, and the sooner we concede it the better. The sooner we admit that we must study and explore the science of heat energy in its higher form, the sooner will we advance in our profession and contribute to its progress. It will be my aim to recall a few of the practical applications in engineering of the principles which thermo-dynamics has established, and thus to give an illustration or rather indication of its value. But before doing so to be strictly conscientious, I must refer to the difficulties to be met with in the study in its higher form. Professor McCulloch says: "Any one acquainted with only the elements of analytical geometry, and of the fluxional calculus, should find no difficulty in understanding all it contains. In this country, however, scientific education, as well as classical, has unfortunately retrograded; and superficiality is the fashion of the day. Hence, some anxious for scientific knowledge, with the least labor and in the shortest time, imagine it might be well in scientific literature to dispense with the calculus. To them no better advice can be given than to begin by studying it thoroughly, if they would reasonably hope ever to comprehend much which would otherwise be unintelligible."

These elements, however, must be firmly fixed in the mind, and thermo-dynamics may justly be considered a thorough test of such a knowledge. When beginning the study of the subject, I thought I had fairly mastered calculus, while engaged in its acquisition I found I was a mere novice, and such too has been the experience of a few of my friends who have already progressed and done good work in the science. But let us not be deterred from the acquisition of a valuable subject because of its difficulty. This

really incites a person to a hard effort, and the gratification which the mastering of an important point gives, forms an incentive to further advance which acts more potently than the repulsive part of the difficulty. Let us not accept the valuable principles reached without making at least an honest effort to follow the masters who have discovered them, and thus make the principles in reality our own. But if our comprehension and efforts will not permit us to do this, let us not cry down the methods by which they were attained, and let us study the principles themselves thoroughly.

There is a wonderful harmony in nature—without it all scientific research would be of no avail. There are certain great invariable laws, some determined and many more not yet conceived, but in our faith in and knowledge of the reliability of those laws exists the only safeguard of advance. This opens up that large realm of reasoning known as "by analogy," and enables us to determine thus, and by analysis, laws which are not directly determinable from our practical experiences or observed phenomena. Heat, the observed and usually acknowledged primary physical source of all energy (though gravitation might on some good grounds be selected as our present ultimatum) beautifully illustrates this harmony when considered as energy, and thus prescribes laws which are afterwards varified in practice, and to which practice conforms and becomes the embodiment of. This is the strongest plea which it seems to me can be urged for the careful study of the mechanical theory of heat, and we will attempt to point out some of the work which has been done in this respect, and leave it to your judgment to decide whether a science which has already accomplished so much is not capable, when many able minds are devoted to its study, of an application and extension which is and will be of incomprehensible value in the ordinary practice of the engineer, and which will greatly contribute to the advance of mechanical engineering.

The specific heat at constant pressure of any permanent gas can be ascertained directly by experiment, not so the specific heat at constant volume. Regnault has made accurate determinations of the specific heat of such gases at constant pressure, and discovered certain laws relative to the same, that the specific heat of such a gas is independent of its temperature and density, and the product of the density and the specific heat is the same constant for all permanent gases. From the velocity of sound, independent of the principles of thermodynamics, the specific heat at constant volume for a permanent gas can be determined, and these two quantities when substituted in an equation of the theoretical value of the mechanical equivalent of heat, expressed as a function of the pressure, volume, dilatability, and the two specific heats of a permanent gas give for this equivalent a theoretical value which agrees with that practically determined by Joule, and recently verified by Professor Rowland. I need not dwell upon the mathematical exposition of this, but reference to Stewart ("Elementary Treatise on Heat," pages 330 & 412), Maxwell ("Theory of Heat," pages 169, 228, & 310), Cotterill ("The Steam Engine Considered as a Heat Machine," page 82) McCulloch ("Mechanical Theory of Heat," page 92) and Rankine ("Steam Engine," page 321) will serve as a verification of the above summation. Permit me to call your attention to this remarkable agreement between theory and practice. The specific heat at constant volume is not directly determinable from experiment, so it is developed from the velocity of sound, and substituting these two independent experimental data (the two specific heats) in a theoretical equation not involving a previous determination of the mechanical equivalent of heat, we ascertain such equivalent from correct theoretical considerations, and it accords with the experimental determination. What a beautiful demonstration of the correlation of the different laws and facts of nature do we here perceive exemplified.

But this will appear rather as an illustration of the beauty and symmetry of the science than as a presentation of a fact of direct utility to the engineer in the practice of his profession, and since it is my special object to call attention to a few of the latter class of facts, I will have to omit the mention of the interesting relations between the physical properties of bodies, such as between the two elasticities and the two specific heats,

gaseous viscosity and the molecular theory of the constitution of bodies, all of which the science teaches and will at once refer to its main application for our own purposes, the work of fluids in engines. It is in this department of our profession that thermo-dynamics has made the deepest impression in practice, and is destined to continue it to a far greater extent. It has taught us the different laws of expansion and work of fluids, and has supplied us with the proper test of the efficiency of different forms of engines. $\frac{T-T_1}{T}$, the limit of efficiency has enabled us to correctly appreciate the progress made, and to definitely point out the direction in which the advance in efficiency and perfection of heat engines lies. To increase the theoretical efficiency, T, the temperature of the fluid at its entrance to the cylinder should be raised, and T_1, the temperature at exhaust lowered as much as possible.

The application of this principle to steam engines implies high steam pressures and great expansion. This was tried within certain limits, and the beneficial results looked for were not realized to the extent expected. The theory was still recognized as true by those who grasped it, but the practical results had not conformed to their expectations. The nature, laws and action of steam were thoroughly investigated, and it became apparent that condensation ensued, owing to heat consumed for internal work during expansion and to the detrimental action of the metal of the cylinder. When the steam enters the cylinder (of a lower temperature than the steam at its initial pressure) it gives out heat to the metal of the cylinder, and to do this sets free latent heat, causing water of condensation to be formed. When the steam in the cylinder expands it performs internal as well as external work, and becomes partially liquefied; as the steam leaves the cylinder, rushing into the condenser, the water mixed with the steam evaporates, abstracting additional heat from the metal of the cylinder. When a fresh volume of steam of initial pressure now enters the cylinder, it comes in contact with the metal of lower temperature, water of condensation is formed and the action continues as indicated above.

Several methods of decreasing this loss presented themselves:

1. The introduction of the compound engine which dividing up the range of temperature between admission and final exhaust, in two or more stages, causes less difference in each cylinder, and therefore decreases the loss by condensation while again the heat abstracted from the first cylinder at exhaust becomes available in the second cylinder.

2. The use of the steam jacket which tends to keep the metal of the cylinder at uniform temperature and thus prevent the initial condensation of steam, and to supply heat to the steam in the cylinder to prevent condensation during expansion.

3. The introduction of a great number of strokes per minute so that less time will be accorded to the steam to impart heat to the metal of the cylinder and to abstract heat during exhaust.

4. The use of superheated steam, since it can emit heat when being admitted to a cylinder of lower temperature without causing water of condensation to form at entrance or during expansion.

Neither of the first three remedies proves entirely efficacious in practice while all have greatly reduced the loss from condensation. An intelligent study of the theory of heat will show, however, that the latter is the only one which offers the possibility of entirely preventing condensation. Perhaps it will need some explanation why the steam jacket can never entirely prevent this loss. It is owing to the fact that the transfer of heat from the steam in the jacket is not as rapid as the transfer of the heat from the internal sides of the cylinder to the steam in cylinder, that the steam on entering the cylinder heats up but a small thickness of metal to its own temperature, owing to the comparatively poor power of conduction of iron. And the steam in the jacket, similarly, heats up to its own temperature but a small thickness of the metal of the cylinder immediately in contact with it; in brief, the poor heat-conducting power of iron does not allow the transfer of heat from the steam in jacket to the steam in cylinder to be practically instantaneous.

There may be some who are opposed

to the introduction of the high speed (as they are popularly termed) or rather "high revolution" engines. But whatever be their practical defects—and they possess some mechanical advantages that we are inclined to think more than counter-balance those defects—the principle is in the right direction, and al ready splendid workmanship and refinement of mechanism and machinery tends to confirm the value theory accords the system.

We will now briefly refer to the use of air. Thermo-dynamics demonstrates its superiority to steam. Its permanently gaseous nature enables it to expand without doing internal work, and its temperature can be raised to a high degree without the objection of a high pressure difficult to control. But practically the few air engines built have as yet not proved a decided success, owing to the difficulty of obtaining a rapid connection of heat to and from the air employed, and the necessity of a larger cylinder than is needed for a steam engine of the same power. Again, very high temperatures of the air cause no inconsiderable strains due to irregular expansion of the metal and a slow oxidation of the metal as well. And so with other forms of fluid engines. Practical difficulties and obstacles have not always permitted the rigid teachings of thermo-dynamics to be precisely realized, though they have in most cases served as an exemplification of its truth. But as long as we have the laws of the mechanical theory of heat to teach us where the possibility of or road to progress lies, better steam and better air and better gas and better fluid engines will in time be built. Even with the fluids and materials at present known, the performance of engines are capable of being doubled, a result by no means too trival to make an honest effort to master the principles which will aid us in securing this end. But who would dare to say in an age when Professor Crooke s fourth state of matter opens up realms of investigation undreamt of, and when Professor Bell's discovery of sound transmitting rays of light potently reminds us that we are but at the threshold of our understanding of the. laws of the universe, who would dare to say that new fluids, materials and conditions will not be discovered that will enable us to extend the limits of temperature between which the fluid can expand in a cylinder, and thus utilize by far the greater portion of the latent power which nature has presented to us in her stores of fuel!

But it may be said: The advances, pointed out above, in the efficiency of engines have not in all cases been instituted by those who have mastered the mechanical theory of heat, and the advances, therefore, are not in all cases the result of the study of the subject. This is partially true, that is while, as far as I can learn, no advances have been secured in the efficiency of heat engines (not including, of course, reduction of friction and better mechanism for transforming the rectilinear motion of the piston) by men who have not been intimately acquainted with, at least, the fundamental principles of heat energy, they have not in all cases mastered the whole subject in its highest mathematical form. But to correctly appreciate and define the advance, the theory of heat energy has always been called into play, and if our progress in the efficiency of heat engines has not been as rapid as we might have desired, and is not as rapid at the present time as desirable, it is owing to a lack of knowledge and understanding of the subject under discussion by some of our more brilliant and experienced minds. There are two methods of gaining knowledge. One by acquiring the laws and results of the experience of others, the other by acquiring the laws by our own experience. Both constitute the acquisition of principles or theory. Both have their uses. But it is a loss of time and it is at the expense of many failures and disappointments which do not contribute to real advance, if we arrive at the same principles by such failures that others have reached before us by whose experience we might have profited. When we have acquired the knowledge of the work that others have done, we are prepared to make further progress, and if the difficulties and obstacles multiply we will be fairly equipped and fully encouraged to meet them. If we then experience failures, they will contribute to real advance instead of demonstrating a fact or law which had already been acknowledged,

and which it was within our power and province to know. Thus too will indorsement of, and investment of capital in, prime movers, advertised as realizing fabulous power be avoided, since our knowledge of the laws of thermo-dynamics will have acquainted us with the principles of the conservation of energy, the impossibility of transgressing certain limits, and will, therefore, indicate or demonstrate the fallacies of the projected scheme.

In conclusion, I must say that I am aware that full justice has not been done to the theme under discussion, nor can, in my opinion, full justice be done to so grand a theme within the limits of a paper of this kind. A complete treatise would have to be written to demonstrate its true importance, and some work like that of Rankine is the best verification of the actual value of the science, and in its study does this value become most potently apparent.

But if I have been able to convince—say, one of you, heretofore uninterested, of the *vitality* of the study, I will feel amply compensated, and will offer no apology for my enthusiasm in the cause.

THE GEOMETRICAL INTERPRETATION OF IMAGINARY QUANTITIES.*

Translated from the French of M. Argand by Prof. A. S. Hardy.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

PREFACE.

THE work now republished† is of that small number which mark an epoch in the history of science. In this short treatise is found the germ of the true theory of so-called *imaginary* quantities. Although generally attributed to the genius of Gauss, this theory was not pointed out by that great geometer until twenty-five years after the publication of Argand's work,‡ and it had been meanwhile re-discovered several times in both France and England. On this point we can cite no testimony more convincing than that of a German geometer, whose recent death is deplored by science. Says Hankel,§ "the first to show how to represent the imaginary forms $A+Bi$ by points in a plane, and to give rules for their geometric addition and multiplication, was Argand, who established his theory in a pamphlet printed in Paris, in 1806, under the title '*Essai sur une manière de representer les quantités imaginaires dans les constructions géométriques.*' Yet this paper did not meet with public recognition until after the insertion of a note by J. F. Francais, in the *Annales de Gergonne*, Vol. IV, 1813, 1814, p. 61, in which, at the same time, Argand* also published two articles. In these articles the subject was so exhaustively treated that nothing new has since been found to add to them, and, unless some older work is discovered, Argand must be regarded as the true founder of the theory of complex quantities in a plane.

" . . . . In 1831, Gauss† developed the same idea, as is well known; but, however great his merit, as bringing this idea to the notice of science, it is none the less impossible to claim for him priority."

From this accurate historical *résumé*, it is seen that the work of Argand remained almost wholly unknown, having been distributed but to few persons, and not put in general circulation. Seven years later, Francais, an artillery officer at Metz, sent to the Editor of the *Annales* the outline of a theory whose germ he had found in a letter written to his brother by Legendre, the latter having obtained it from another author whose name he did not give. This article came to the notice of Argand,

* Essay on the Geometrical Interpretation of Imaginary Quantities, by R. Argand. Second edition with preface by M. J. Hoüel, and extracts from the *Annales* de Gergonne, Paris, Gauthier-Villars, 1874. From the French, by Prof. A. S. Hardy, Dartmouth College.

† 1st edition, Paris. Duminil-Lesueur, 1806.

‡ Anzeige zur "*Theoria residuorum biquadraticum Commentatio secunda*," 1831 (Gauss Werke, t. II, p. 174).

§ *Vorlesungen uber die complexen Zahlen und ihre functionem.* (Leipzig, 1867, p. 82).

* Vol. IV, p. 133, and Vol. V, p. 197.

† Works, Vol. II, p. 174,

who immediately wrote Gergonne a note in which he made himself known as the author of the work cited in Legendre's letter, and in which he gave quite a complete summary of his pamphlet of 1806. This double publication gave rise to a discussion in the *Annales*, in which Francais, Gergonne and Servois took part, closing with a remarkable article, in which Argand explained more satisfactorily certain points in his theory, especially his demonstration of the fundamental proposition of the theory of algebraic equations, the simplest yet given, which subsequently Cauchy only reproduced, in a purely analytic, but less striking, form. These various articles, the natural sequel to Argand's pamphlet, published in a *Recueil* now very rare, are collected in an appendix to this volume. Notwithstanding their appearance in a scientific journal so well known, the views of Argand were wholly unnoticed, as appears from the fact that twenty-two years after the publication of the essay they were re-stated both by Warren, in England, and Mourey, in France, apparently without any knowledge on their part of their earlier exposition. Nor did they themselves succeed in attracting the attention of geometers, although the researches of Mourey were given in the *Lecons d'Algèbre* by Lefébure de Fourcy, and two articles, supplementary to his first work, had been published by Warren in the Philosophical Transactions. Only after Gauss had spoken, were these views taken up in Germany. They soon became familiar to English geometers, and were the starting point of Hamilton's theory of Quaternions, while, in Italy, Bellavitis made them the basis of his *Méthode des Équipollences.** In France, Argand's theory was worked over, without material addition, till its adoption by Cauchy, who expounded it in his *Exercices d'Analyse et de Physique mathématique*,† with a complete historical notice rendering Argand full justice.

In the work of this modest savant of Geneva is to be found the origin of many subsequent researches, some of which have thrown unexpected light both upon the mystery which has so long enveloped negative and imaginary quantities, as well as upon the general theory of functions, by affording a definite geometrical interpretation. Others, as yet of less importance, but perhaps destined in the future to render great services, have resulted in the creation of new methods in analytical geometry, among which may be cited those of Möbius, Bellavitis, Hamilton and Grassman. Unable to avoid the constant presence of negative and imaginary quantities in the results of analysis, or to surrender the important advantages following the use of their corresponding symbols, mathematicians had for a long time been content to employ them without fully accounting for their true nature, regarding them as signs of operations which in themselves had no meaning, yet which, under certain rules, led surely and directly, though in an obscure and mysterious manner, to results which other quantities would not have yielded, except indeed by long and difficult processes, involving the discussion of an indefinite number of particular cases. It is at last seen, however, that the impossibility of negative quantities is, in general, only apparent, and results from a generalization of the idea of quantity without any modification of the corresponding analytical operations. An analogous case is found in the very elements of arithmetic, which, however, has given rise to no difficulty. The operation of division cannot be exactly performed if we are restricted to whole numbers. But if unity be divided into equal fractions, the division is always possible, and the result becomes a *complex* expression, consisting of two numbers, one indicating multiplication, the other division. Hence arises a new class of quantities, fractions, subject to operations to which are applied the same names given to the operations on integers, which they include as particular cases. But the definitions of multiplication and division have been therefore carefully modified, to render them applicable to the new quantities. By proceeding in an analogous manner in addition and subtraction, the meaning of a negative quantity has been definitely fixed. So long as the problem is restricted to the simple determination of magnitude, the subtraction $a-b$ is im-

* *Exposition de la Methode des Equipollences Guisto Bellavitis.* Traduit de l'Italien par C. A. Laisant, Paris. Gauthier-Villars, 1874.

† Vol. IV, p. 157.

possible and absurd, if $b>a$. But if, instead of a series of magnitudes, extending from zero in a single direction, we are concerned with a series extending indefinitely in two opposite directions, and if we call *addition* an operation which consists in starting from a certain quantity in one of these two directions, and *subtraction* an inverse operation, consisting of motion in the opposite direction, thus defined, both operations will be always possible and their results as real as those of a purely arithmetical addition.

To represent these results in a simple manner, we are led to write before the symbol, representing any quantity, a sign indicating the direction in which it is estimated. Such is the true meaning of negative quantities.

This extension of the meaning of quantity and of the operations to which it is subjected, may be carried still further. But this further representation of quantity makes the use of a geometrical notation, which, within the limits of its application, is the most luminous and complete of all, almost indispensable. Suppose the quantity sought be subject to two causes of variation, and to depend upon two magnitudes which can be represented by any two co-ordinates fixing the position of a point in a plane. The operation of extracting the square root, for example, in the preceding case of a single variable co-ordinate, was possible only when the quantity so operated upon was of the kind denoted by plus unity. So long as $\sqrt{a}$ corresponds to the construction of a mean proportional between a and $+1$, $\sqrt{-b^2}$ indicates an impossible operation, and no point of the locus corresponding to a single variable co-ordinate can represent this result. But if both co-ordinates are made variable and the restriction to a single line be abandoned, and the definition of the extraction of the square root be modified, the case is otherwise. The quantities considered do not then depend upon a single magnitude, but on two, and are for this reason called complex quantities. In operating on such a quantity, both of the quantities on which it depends are affected, exactly as in operating on a fraction we affect its two terms. Thanks to the introduction of both new quantities and new definitions of operations, $\sqrt{-b^2}$ no longer indicates an impossible operation, and the term *imaginary* is no more applicable to such a result than to fractions or negative quantities. Such is the fundamental and immediate consequence of Argand's conception. Symbols of the form $a+b\sqrt{-1}$, to which all analytical results have been reduced, are no longer either impossible or incomprehensible; they are a system of two numbers a and b, which are combined with each other just as are the co-ordinates of a point in a plane. Thenceforth, the brilliant results of the powerful analysis of Cauchy were to be translated into a geometrical language speaking to the eyes, and the discussion of formulæ became a simple problem of the Geometry of Position, subsequently completely solved by Riemann. The theory of complex quantities which, by the discoveries of Cauchy, had become the basis of the theory of functions, thus received at the same time a new confirmation, placing them beyond all the doubt and objections to which they had been before exposed. Such are the eminent services rendered by the discovery of Argand both to Analysis and the Philosophy of Mathematics.

But geometry, as well as analysis, though to a less degree, has profited by the introduction of these conceptions, founded on the discovery of a new bond between these two branches of the science. In Argand's work are found the beginnings of a very general method of plane analytical geometry, developed later by M. Bellavitis with great success, furnishing a uniform process for the discussion both of problems in elementary geometry and the more advanced theory of curves. The advantage of this method consists in the introduction into the calculations of the points themselves instead of their co-ordinates, and the consequent choice at the last moment of the most convenient system of reference. Argand was less successful in his attempts to extend his method of representing points to space of three dimensions. Indeed, this problem involved difficulties far greater than those which he had just overcome, and not till after thirty years did Hamilton at last surmount them.

We should have taken great pleasure in giving our readers some information relative to the author himself of this important tract. With this in view, we applied to M. R. Wolf, as more thoroughly acquainted with the history of science in Switzerland than any one else, and to whom we are indebted for a biographical collection, as remarkable for its profound learning as for its attractive style. M. Wolf at once kindly caused inquiries to be made in Geneva, Argand's native city. Unfortunately, the information he obtained, through Prof. Alfred Gautier, is contained in a few brief lines here cited: "I readily found the registry of birth, on July 22d, 1768, of Jean-Robert Argand, son of Jacques Argand and Éve Canac, very probably the author of the mathematical paper in question. I learn from one who knew his family that he was for a long time a book-keeper at Paris, and I presume that he died there. He was not a near relation of Aimé Argand, * and pernaps not of the same family. He had one son who also resided in Paris." M. Wolf subsequently learned that Argand also had a daughter named Jeanne-Francoise-Dorothée-Marie-Elizabeth, married to Félix Bousquet, with whom she went to Stuttgart, where he had obtained some unimportant situation. If we add to this that, about 1813, Argand lived at Paris, *rue de Gentilly, No.* 12, as indicated in his own handwriting on the cover of the copy sent to Gergonne, we shall have stated all we have been able to learn of this original man, whose modest life will remain unknown, but whose services to science Hamilton and Cauchy have deemed worthy the gratitude of posterity.—J. Houel.

1. Let a be any arbitrary quantity. If to this quantity another equal to it be added, we may express the resulting sum by $2a$. If we repeat this operation, the result will be $3a$, and so on. We thus obtain the series a, $2a$, $3a$, $4a$, ..., each term of which is derived from the preceding by the same operation, capable of indefinite repetition. Let us consider the series in reverse order, namely, ..., $4a$, $3a$, $2a$, a. As before, each term of this new series may be regarded as derived from the preceding by an operation which is the reverse of the former; yet, between these series there is this difference: the first may be indefinitely extended, but the second cannot. After the term a, we should obtain 0, but beyond this point the quantity a must be of such a nature as to permit our operating on zero as we did on the other terms . . . . ., $4a$, $3a$, $2a$, a. But this is not always possible. If, for example, a represents a material weight, as a gram, the series . . . . ., $4a$, $3a$, $2a$, a, o, cannot be extended beyond 0; for while we may take 1 gram from 3, 2 or 1 gram, we cannot take it from 0. Hence the terms following zero exist only in the imagination; they may, therefore, be called imaginary. But instead of a series of weights, let us consider them as acting in a pan A of a balance containing weights in the other pan also; and for the purpose of illustration, let us suppose the distance passed over by the arms of the balance is proportional to the weight added or withdrawn, which indeed would be the case if a spring were adjusted to the axis. If the addition of the weight n to the pan A moves the extremity of the arm A a distance n', the addition of the weights $2n$, $3n$, $4n$, ..., will cause this same extremity to move over the distances $2n'$, $3n'$, $4n'$, ..., which may be taken as measures of the weight in the pan A: this weight is zero when the pans are balanced. By placing the weights n, $2n$, $3n$ . . . . ., in the pan A, we may obtain the results n', $2n'$ $3n'$ . . . . ., or, by starting with $3n'$ and withdrawing the weights, the results $2n'$, n', 0. But these results may be reached not only by taking weights out of the pan A, but also by adding them to the pan B. Now the addition of weights to the pan B can be continued indefinitely; and in so doing we shall obtain results expressed by $-n'$, $-2n'$, $-3n'$, ..., and these terms, called *negative*, will express quantities as real as did the positive ones. We, therefore, see that when two terms, numerically equal, have opposite signs, as $3n'$, $-3n'$, they designate the different positions of the balance arms, such that the extremity indicating the weight is in both cases equally distant from the point 0. This distance may be considered apart from *direction*, and be then called ***absolute***.

* A friend and associate of the brothers Montgolfier, who invented the lamp of that name. (1755-1803.)

Let us consider the origin of negative quantities in a case of another kind. If in counting a sum of money we adopt the franc piece as unity, we may operate successively by subtraction on this sum, and render it zero by taking away a certain number of francs. At this point the operation becomes impracticable, and, consequently,—1 franc,—2 francs, ... are imaginary quantities. Take now the nominal franc as unity, for the purpose of estimating a fortune made up of credit and debit. What we call a *diminution* of this fortune might take place either by a decrease in the number of francs on the credit side, or by an increase in the number on the debit side, and by continuing either process we should have a negative fortune of -100 francs, -200 francs, ... Such expressions signify that the number of francs of debt, considered abstractly, exceed by 100, 200, those of credit. Thus -100 francs, -200 francs, ..., which in the former case can express only imaginary quantities, here represent quantities as real as those denoted by positive expressions.

2. These ideas are very simple; yet it is not so easy, as it at first seems, to set them forth clearly, and to give them the generality which their application requires. Moreover, the difficulty of the subject will not be questioned if we remember that the exact sciences had been cultivated for many centuries, and had made great progress before either a true conception of negative quantities was reached or a general method for their use had been devised. Moreover, it was not our intention to endeavor to state these principles more rigorously or more clearly than they are to be found in the works which deal with this subject; but simply to make two remarks on negative quantities. First, that whether a negative quantity is real or imaginary,* depends upon the kind of magnitude measured; and, second, when we compare two quantities which are of a kind yielding negative values, the idea involved in their ratio is complex, including, 1° a relation dependent on number, considered *absolutely;* 2° a relation of *direction*, or of the sense in which they are estimated, a relation either of identity or opposition.

3. If now, setting aside the ratio of absolute magnitude, we consider the different possible relations of direction, we shall find them reducible to those expressed in the two following proportions:

$$+1 : +1 :: -1 : -1,$$
$$+1 : -1 :: -1 : +1.$$

Taken directly and by inversion, these proportions show that the signs of the means are alike or different when those of the extremes are so. Now let it be required to find the geometrical mean between two quantities of different signs, that is, to find the value of x in the proportion

$$+1 : x :: x : -1.$$

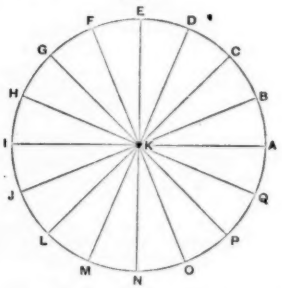
Here we encounter a difficulty, as when we wished to continue the decreasing arithmetical progression beyond zero, for x cannot be made equal to any quantity, either positive or negative; but, as before, the quantity which was imaginary, when applied to certain magnitudes, became real when to the idea of *absolute number* we added that of *direction*, may it not be possible to treat this quantity, which is regarded imaginary, because we cannot assign it a place in the scale of positive and negative quantities, with the same success? On reflection this has seemed possible, provided we can devise a kind of quantity to which we may apply the idea of direction, so that having chosen two opposite directions, one for positive and one for negative values, there shall exist a third—such that the positive direction shall stand in the same relation to it that the latter does to the negative.

4. If now we assume a fixed point K (Fig. 1) and the line KA be taken as positive unity, and we also regard its direction, from K to A, and write $\overline{KA}$ to distinguish it from the line KA as simply an absolute distance, negative unity will be $\overline{KI}$, the vinculum having the same meaning as before, and the condition to be satisfied will be met by KE, perpendicular to the above and with a direction from K to E, expressed in

* The sense in which these words are used is sufficiently determined by what precedes: the extension here given to their ordinary meaning seems permissible, and is moreover not wholly new. In optics, what is called the imaginary focus, as distinguished from the real, is the point of intersection of rays which have no existence, in a physical sense, and which can be considered, in some sort, as negative rays.

like manner by $\overline{KE}$. For the direction of $\overline{KA}$ is to that of $\overline{KE}$ as is the latter to that of $\overline{KI}$. Moreover we see that this same condition is equally met by $\overline{KN}$, as well as by $\overline{KE}$, these two last

Fig.1.



quantities being related to each other as $+1$ and -1. They are, therefore, what is ordinarily expressed by $+\sqrt{-1}$, and $-\sqrt{-1}$. In an analogous manner we may insert other mean proportionals between the quantities just considered. Thus to construct the mean proportional between $\overline{KA}$ and $\overline{KE}$, the line CKL must be drawn so as to bisect the angle AKE, and the required mean will be $\overline{KC}$ or $\overline{KL}$. So the line GKP gives in like manner the means between $\overline{KE}$ and $\overline{KI}$, or between $\overline{KA}$ and $\overline{KN}$. We shall obtain in the same way $\overline{KB}$, $\overline{KD}$, $\overline{KF}$, $\overline{KH}$, $\overline{KJ}$, $\overline{KM}$, $\overline{KO}$, $\overline{KQ}$, as means between $\overline{KA}$ and $\overline{KC}$, $\overline{KC}$ and $\overline{KE}$ . . . . and so on. Similarly we might insert a greater number of mean proportionals between two given quantities, and the number of constructions involved in the solution would be equal to the number of ratios in the required series. Thus, for example, to construct two means, $\overline{KP}$, $\overline{KQ}$, between $\overline{KA}$ and $\overline{KB}$, we should have the three ratios $\overline{KA} : \overline{KP} :: \overline{KP} : KQ :: KQ : \overline{KB}$, and necessarily, angle AKP=angle PKQ=angle QKB, the vinculum indicating that these angles are similarly situated with respect to the bases AK, PK, QK. Now this may be effected in three ways, namely, by trisecting 1° the angle AKB; 2° the angle AKB increased by 360°; 3° the angle AKB increased by twice 360°, giving the three constructions of Fig. 2, 2 bis, 2 ter.*

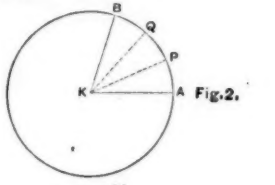


Fig.2.

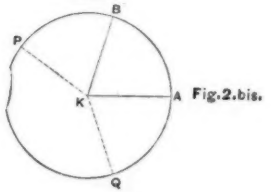


Fig.2.bis.

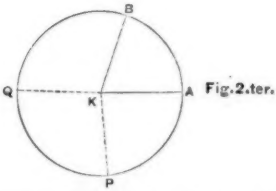
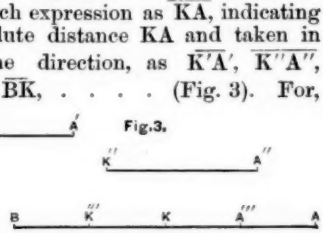


Fig.2.ter.

5. Observe, further, that the relations just established between the quantities $\overline{KA}$, $\overline{KB}$, $\overline{KC}$, ..., do not require that the directions which these quantities fundamentally involve should be estimated from a single point K; but that these relations are equally true for every such expression as $\overline{KA}$, indicating an absolute distance KA and taken in the same direction, as $\overline{K'A'}$, $\overline{K''A''}$, $\overline{K'''A'''}$, $\overline{BK}$, ... (Fig. 3). For,

Fig.3.



following with respect to this new quantity the same reasonings as before, we see that if $\overline{KA}$, $\overline{K'A'}$, $\overline{K''A''}$, ..., are each positive unity, $\overline{AK}$, $\overline{A'K'}$, $\overline{A''K''}$,

* The principle on which these constructions rest, stated generally, is that the ratio of two radii KP, KQ, making an angle QKP, depends on this angle when these radii are considered as drawn in a certain direction, and that this ratio is the same as that of two other radii KR, KS, making the same angle; but although this principle is, in a way, an extension of that on which the geometrical ratio of a positive and negative line was established, it is here only an hypothesis whose legitimacy must be proved, and whose consequences, till then, are to be independently confirmed.

are negative unities; that the mean proportional between $+1$ and -1 can be expressed by any line whatever, equal in length to the above and perpendicular to them in direction, and taken at pleasure in either of its two directions, and so on. To make this clear, consider a particular case as, for example, a given force assumed as unity and represented by $\overline{KA}$, acting parallel to KA in the direction from K to A, its point of application being arbitrary; this unit force may be expressed by a line parallel to KA, with any point as an origin. The negative unit would be an equal force with a parallel action line, but acting from A towards K, and could likewise be represented by a line drawn from any point parallel to the former one, but in an opposite direction. All that is necessary, then, to the application of the principles already developed regarding radii is that the qualities, indicated by plus and minus, which we attribute to a certain quantity, should depend upon opposite directions between which there exists a mean; and that the relations between all lines which will represent such a quantity be then conceived as the same which existed between the radii.

6. From these reflections it follows that we may generalize the meaning of expressions of the form $\overline{AB}$, $\overline{CD}$, $\overline{KP}$, ... , every such one representing a line of a certain length, parallel to a certain direction, the latter taken definitely in one of the two opposite senses which this direction presents, with any point as an origin; these lines themselves being capable of representing magnitudes of another kind. As they are to be the subject of the following investigations, it is proper to give them some special designation. They will be called *lines having direction*, or simply, *directed lines.** They will be thus distinguished from *absolute* lines, whose length only is considered without regard to direction.†

7. Applying the terms of common usage to the different varieties of directed lines which arise in connection with a primitive unit $\overline{KA}$, it is seen, that every line parallel to the primitive direction is expressed by a real number, that those perpendicular to it are expressed by imaginaries of the form $\pm a\sqrt{-1}$, and, finally, that those having other directions are of the form $\pm a \pm b\sqrt{-1}$, and are composed of a real and imaginary part. But these lines are quantities quite as real as the positive unit; they are derived from it by the association of the idea of direction with that of magnitude, and are in this respect like the negative line, which has no imaginary signification. The terms *real* and *imaginary* do not therefore accord with the above exposition. It is needless to remark that the expressions *impossible* and *absurd*, sometimes met with, are still less appropriate. The use of these terms in the exact sciences in any other sense than that of *not true* is perhaps surprising.*

An absurd quantity would be one whose existence involved the truth of a false proposition; as, for example, the quantity x, satisfying at once $x=2$, $x=3$, whence $2=3$. The admission of such a quantity into the calculus would entail consequences as contradictory as $2=3$; but the results obtained from the use of the so-called imaginaries are in all respects conformable to those derived from reasonings in which only real quantities appear. We might thus foresee the impropriety of a nomenclature which classifies truly absurd quantities and the even roots of negative quantities together, and it was a consciousness of this impropriety which first gave rise to the ideas developed in this essay. It is thus that we are led to a new nomenclature.†

THE right of way for the first hundred miles of the Canada Pacific Railway has been purchased. It ends at the western boundary of the Province of Winnipeg.

[*The *directed lines* of Argand are, of course, Hamilton's vectors, and the above principle is simply a statement of the fundamental conception of a vector, *i. e.* that all quantities having direction as well as magnitude are vectors, and that vectors are not changed by translation without rotation.—TRANS.]

†The expression *lines having direction* is only an abbreviation of *lines considered with reference to their direction.* This remark will show that we do not pretend to create a new nomenclature, but, by this denomination, both to avoid confusion and secure brevity.

*There was a time, when led by the very nature of the case to admit negative values in the discussion of abstract quantities, geometers, having apparently some difficulty in imagining that *less than nothing* could be *anything*, applied to such values the term *fausses.* The use of this word, in its original vicious sense, ceased when the conception under which it arose was rectified.

†It is amost needless to observe that we refer only to the confusion which arises from the terms, and that a corresponding confusion of ideas is not implied.

MODERN STEEL AS A STRUCTURAL MATERIAL.

By Mr. W. Worby Beaumont, Associate Member Inst. C. E.

From Papers of the Society of Engineers.

THE object of this paper is not to bring forward any new experiments on the properties of steel as employed in constructive work, but to invite discussion on a few points which may occur to the engineer, to whom it seems desirable to consider the relative advantages of mild steels and iron in some mechanical or constructive work. For several years the substitution of steel for iron in various structural work has occupied the attention of engineers and metallurgists, but the progress which has been made, compared with the hopes that were entertained when steel made by the Bessemer process became cheap enough to make its cost, strength for strength, comparable with that of iron, has not been great. There are classes of structures in which a reduction in weight would be a material advantage, even when attended with an increased total cost. Ships, boilers, and girders may be instanced as examples. In this direction, therefore, engineers turned their attention, with a view to the application of steel. The difficulties, however, which attended the manipulation and connection of steel in structures largely composed of plates checked its application. Many failures attended the attempts to use it, chiefly resulting from apparently anomalous behavior of the metal under what were considered similar conditions, but more, perhaps, owing to the special treatment which it required as compared with iron. Those who had been long accustomed to the manipulation of iron were unable to depart from past practice sufficiently to operate upon the new material, with all the careful attention to its different properties which these demanded. Thus, although the difference in its behavior in the hands of the smith and plate worker, as compared with iron, was considered in several of the details of manipulation, certain other peculiarities were lost sight of in the assemblage of parts, which resulted in the destruction of work when almost completed. Even twenty years ago, before the modern cheap steels had been offered, steel made by the crucible process had been successfully employed on a small scale for boiler work. Very careful attention to the behavior of steel under treatment had no doubt been observed, as it might easily be on a small scale; but when, some years after, attempts were made to use Bessemer steel for boiler and bridge work difficulties arose, some of which were attributed to the nature of the material and some to the want of thorough care on the part of the workmen. Even when plates of this material cost more than iron for boiler construction, and very much more than iron for bridge and girder work, attempts were made to use it for the latter on account of the several advantages which would arise from a decrease in the permanent load of bridge structures. Failures, however, of parts of these structures both before and after completion, due to the want of the observance of the special treatment which the material demanded, discouraged its employment. The endeavors of steel makers during the past few years have, therefore, been directed to the production of steel possessing properties so far similar to wrought iron that no great departure from the methods of working this material need be made. Apart from the frequent want of uniformity in the mechanical properties of the Bessemer steel plates of a few years ago, it generally exhibited an absence of toughness, which not only made it difficult of manipulation in the hands of the plate smith, but caused its destruction after being built into a structure. Its uncompromising rigidity rendered it incapable of accommodating itself to, and gradually eliminating from, itself, the residual strains originating in unequal heating and cooling, and also to the unequal strains visited upon it by other parts of a structure, of which it

was made to form a part, either by riveting or other modes of connection. It was not that the steel did not appear to possess the qualities when tested in the testing machine, but its behavior was apparently different when employed in full size pieces or plates, from that exhibited when tested in small pieces in the machine. This difference indicated that there were differential internal molecular strains resident in the whole plate which were eliminated when the same plate was cut into strips. This elimination, it was considered, could not take place in the whole plate on account of the harshness of its material. Annealing was resorted to, but only with partial success, the complex nature of the strains in a plate of the material, even when cooled slowly, being sufficient, when aggravated by extraneous strains to cause its rupture. It is perhaps not necessary here to consider the nature of the strains in a plate of iron or steel resulting merely from slightly differential contraction in cooling, but it may be observed that though small, these strains may have a material influence on the strength of a plate as a whole, and that they would be greater in the thicker plates. This may be referred to here after.

The necessity of imparting to steel plates the toughness characteristic of good wrought iron has thus induced steel manufacturers to devote their attention to the production of steel possessing great ductility. It is on this point that much might be said, because in the search for toughness the advantages which the employment of steel in some structures seemed at one time to promise, are being almost lost sight of. Not only are these advantages likely to be lost, but the great ductility being imparted to soft steels and ingot iron, in search for this necessary toughness, seems likely to give us a material inferior in some essential qualities to much of the wrought iron hitherto in use. Toughness in plates has not been obtained, but instead thereof great ductility attended with low elastic strength.

It may be premised that the structural value of a metal will be proportionate to the degree in which it combines high ultimate strength with high elastic limit and wide range of elastic and ductile extension, or in proportion to the relation in which it combines toughness with strength. Thus a metal which possesses high ultimate strength and high elastic limit, with small ranges of extension, will not have great structural value, as it will not be capable of withstanding impact strains. Again, a metal possessing high ultimate strength with low elastic limit will have small value for structural purposes, as, though high ultimate strength is an essential property, the limit of elasticity determines in almost all cases the sectional area, and, therefore, weight of metal required for a given duty. A high elastic limit, with considerable elastic extension, must be obtained, combined with great toughness beyond that limit, or in other words, a high elastic limit must be attended by a considerable range of extension both within and beyond that limit, combined with high ultimate strength.

The tendency, however, in the production of the modern mild steels and ingot irons, which will eventually no doubt supplant wrought iron made by the puddling process, is to make a metal which is far from combining these properties in such relations that it is best suited for structural purposes, or so as to offer those advantages which were at one time supposed to be attainable by the use of steel.

The best index to the comparative structural value of different materials is probably that obtained by the application of Poncelet's formulæ as simplified and made applicable for practical purposes by Robert Mallet. This formulæ expresses by coefficients $\mathrm{T}e$ and $\mathrm{T}r$ and $\mathrm{T}e'$ and $\mathrm{T}r'$ the work done by an extending or compressing force upon an elastic prismatic body, at the point where its elasticity becomes permanently impaired, and its form distorted, and at the further point where rupture occurs, or, in other words, it expresses the balance in any material between strength and toughness, and was designed to give a more exact index to the structural value of materials than was given by the early experimenters down to the days of Telford, when the force necessary to produce rupture was alone considered. The formulæ are probably known to most of the members

of the society, having been given by Mallet in a paper "On the Coefficients of Elasticity and of Rupture in Wrought Iron," published in vol. XVIII of the "Proceedings" of the Institution of Civil Engineers, and subsequently employed by Dr. Pole in his book on "Iron as a Material of Construction," but they may be repeated here.

Let L = the length of the prism;
l = the unit of length;
A = the transverse sectional area of the prism;
i = the extension, or compression which is proportionate to $\frac{l}{L}$;
P = the force of extension or compression which is proportionate to A; and
e = the elastic resistance which balances P, or the modulus of elasticity.

The force P is, of course, variable between o and i,

$$i=\frac{PL}{eA} \text{ and } P=\frac{eA}{L}i.$$

If x be any small extension, or compression less than the nth part of i, P corresponding to $x=\frac{eA}{L}x$. The work done in extending, or compressing through the infinitely small additional range $\triangle' x$ (assumed uniform) $=\frac{eA}{L}x\triangle' x$, and the whole work done when i=the compression or extension at which the elasticity of the material is permanently changed, or the elastic limit reached, is

$$Te=\frac{eA}{L}\int_o^i x\triangle' x=\frac{1}{2}\frac{eA}{L}i^2,$$

or $Te=\frac{1}{2}ei^2$, or simply $=\frac{1}{2}Pi$;

for the unit of length and section. The value of the coefficient Tr is arrived at in the same way, by substituting the corresponding values for P and i due to the moment of crushing or of rupture. Thus for a material having under tensile strain an elastic limit P of 12 tons per square inch, and elastic extension e of 0.02 inch in a foot of length, and having an ultimate of 22 tons per square inch and a total extension of, say, 1 inch, the coefficient

$$Te=\frac{P\times 2240\times \frac{e}{12}}{2},$$

or

$$Te=\frac{12\times 2240\times \frac{0.02}{12}}{2}=22.31,$$

and

$$Tr=\frac{22\times 2240 \text{ by } \frac{1.0}{12}}{2}=2052.5,$$

while with another material having an elastic limit of, say, 14.22 tons, elastic extension 0.024 inch; ultimate strength, say, 23 tons, and total extension of 1.6 inch in a foot, the coefficient Te=31.8 and Tr 3501.

In order to determine the relative structural values of several materials, it is thus necessary to take Te and Tr simultaneously into consideration, though Te is the coefficient of the greater importance in most structural work.

About a dozen years ago Bessemer metal was offered for bridge and ship construction, which in the testing machine showed an ultimate tensile strength of from 34 to 40 tons per square inch; an elastic limit from 20 to 23 tons, and a range of ductile extension of from 10 to 18 per cent., while the tests of plates considered suitable for the shells or barrels of boilers showed figures not much lower than these. The failures which occasionally attend the application of this steel, however, discouraged the extension of its application by engineers, who hoped that greater uniformity in the mechanical properties of the metal would gradually be obtained by the steel makers. A steel of somewhat lower tenacity and greater ductility, attended by great uniformity in composition and behavior, was then produced, and this indicated that steel makers and engineers must look to steel of milder character for the removal of the difficulties which had attended the structural application of cheap steels, that is, steels not produced by the crucible. The result of this was that engineers specifying steel for, say, bridge-work, stipulated that it should not possess more than a certain maximum tenacity, a reversal of the stipulation that had always and does obtain with respect to iron. As a further result of this, and to ensure that the

harder steels of comparatively high tenacity, but less uncertain character, should not be used in the construction of bridges, the Board of Trade regulations upon the subject limited the tensile strain on any part of a structure to 7 tons per square inch. This has led to the endeavor on the part of all steel makers to produce the very mild soft steels now largely used, some of which afford the engineer no help towards producing the lighter structures which a dozen years ago it was promised that steel would give them. Boiler shells must be made nearly or quite as thick as if they were constructed of iron.

As an instance in illustration reference may be made to the results of a series of experiments made on iron and mild steel, in order to determine their respective values for high-pressure boiler construction, and described by Mr. David Greig and Mr. Max Eyth in a paper read before the Institution of Mechanical Engineers, in June, 1879. Amongst other experiments, the mechanical properties of mild steel and Yorkshire plates under tensile strain was determined. The plates—both iron and steel—were obtained from Messrs. John Brown & Co. and Messrs. Cammell & Co. In the paper referred to the mean tensile strength, elastic limit and extension are given as follows:

	Ultimate strength. Tons per square inch.	Elastic limit.	Extension per cent.
Iron plates....	22.27	16.06	36.2
Steel plates....	25.80	16.74	28.3

The extension given is in a length of 6 inches. If all reference to the secondary elastic limit, which may be induced by repeated application of strain up to and slightly exceeding the elastic limit of each preceding test, be omitted, it will be seen that the so-called steels, to which the above figures relate, present scarcely any structural advantage over iron. The elastic limit is nearly the same, and though its ultimate strength is greater than that of iron, its ductility, as shown by its range of extension, renders its greater ultimate strength of little value; for very long before it can be strained to that limit, in any structure, it stretches so much that the accumulation of strain is prevented, and this may be shown to take place in bridge as well as boiler structures. With respect to the latter, Messrs. Greig and Max Eyth observe that "the tensile and shearing strength of the material supplied for these tests by some of the most experienced makers of steel, and by them, no doubt, considered the best for the purpose, has in the experiments proved to be not more than 10 per cent. above that of the iron supplied at the same time, and its want of hardness, as distinct from tensile strength, has proved to be a very serious disadvantage in boiler work. What the trade now requires is a return to a harder material of increased tensile strength without losing the homegeneity which is as present obtained at the expense of hardness." Again, in speaking of the results of the test, under hydraulic pressure, of the complete boilers made of this steel, they say, "the compression of the rivet and elongation of the rivet hole resulted invariably in leakage which prevented the necessary pressure from being obtained. Each rivet became its own safety valve, and the strain put on the weakest part never reached more than 70 per cent. of the breaking strain. This is the point where additional hardness of the material would be most useful, as it would prevent the opening of the rivet holes, which now makes a boiler useless long before the breaking strain is reached." This evidence is, therefore, to the effect that no structural advantage is obtained by the use of these steels in place of iron.

If we turn now to the result of tests, made by Mr. Kirkaldy, of Siemens' mild steel, we find that the mean results for plates of from 0.37 to 0.70 in thickness, annealed and unannealed are as follows:

	Ultimate strength. Tons per square inch.	Elastic limit.	Extension. per cent.
Unannealed....	31.02	14.50	23.4
Annealed.....	28.84	12.84	24.6

From these figures it will be seen that though this material (like that used at Messrs. Fowler's Works) may be very safe, it presents little structural advantage over iron plates, the limit of elasticity being low, permanent set taking place at as low as 12.84 tons per square inch when the plates are annealed. It is, however, observable that though the extension of this metal reaches a total of 24.6 per cent. it is less than 11 per cent. annealed, and under 7 per cent.

unannealed at a strain of 26.78 tons, thus indicating very considerable toughness and probably greater value as a structural material than that tested by Messrs. Greig and Max Eyth.

Material described still more recently gives the engineer even less of hope that the modern steel for structural purposes will enable him to produce lighter structures than he can do with iron. It would even appear that greater hope of obtaining a material of high structual value is to be found in iron; for it was recently stated at a meeting of the Iron and Steel Institute by a member that he had been experimenting with puddled iron, the elastic limit of which ranged from 19 to 20 tons, while its ultimate strength was 29 tons and its elongation between these strains was 23 per cent. in a length of 8 inches. The elongation within the elastic limit was not mentioned. Unless a higher elastic limit can be obtained no advantage in a structural sense is secured. High ultimate strength is a comparatively useless quality if the elastic limit is low, and great range of extension is also of no service. In bridge work a very high range of extension is useless, because the members under tension would elongate if strained beyond the elastic limit, to a greater extent than the members under compression would compress, and thus the structure would fail by the destruction of the balance in the disposition of the strains on the different parts. Even if the material showed a range of compression equal to its range of extension this would remain equally true, because in order to secure the necessary resistance to bending or buckling, members under compression must be of greater sectional area than is indicated by the static strain. Thus a higher elastic limit is the first essential in steel for structural purposes. This it appears can only be obtained by making the steel harder, which, by the Bessemer process at least, if not by other largely used processes, it seems cannot be secured without other attendant qualities or properties which make the material difficult to work, and more or less uncertain in its behavior under mechanical treatment. Whether this is really now so, or must continue so, it remains for the steelmakers to show, but it does at least seem plain, that even with some of the so-called mild steels a little misgiving is pardonable on the part of the boilermaker, who wonders what he may find in a boiler shop to-morrow where he has left a nearly or quite finished boiler to-night. Not only, moreover, is this mild steel way of getting over the difficulties attending the use of the strong steels likely to rob engineers of much that the latter material promised; but by the still existing custom of denominating what is really iron by the term steel, we are like to lose the advantages gained by using the harder steels where that has been possible, for already a good deal of so-called steel, in which there is not much more carbon than there is in a Lowmoor bar, is being worked up into steel rails and steel tires. It is true that rails of very hard steel do not wear quite so well as those of a tougher quality, but it remains to be seen whether some of the very mild metal being rolled into rolls to-day may not soon acquire battered heads under the heavy traffic of modern locomotives. Such rails will not laminate, but it remains to be seen whether splitting will not result from the deformation by battering.

It will have been observed that in this short paper the attention of the writer has been almost wholly confined to references to plates. This has been done because chiefly in plates improvement has to be looked for from the steel makers. With bar steel, the difficulties in manipulation and connection in structures have not been so great as with plates, and failures, whether due to imposed or internal differential molecular strains, have not been so frequent; sections are less in area and forms less capable of initiating and transmitting destructive strains. Consequently, mild bar steel need not be so ductile as mild plate steel, and hence the structural value of mild bar steel is much higher than that of plates, and engineers can use it to advantage. In the course of a very interesting lecture delivered by Dr. Siemens at the Royal United Service Institution in March, 1879, he gave a table showing the results of a serious of tests of mild and hard steel bars up to, and slightly beyond their elastic limit. This table is of great value as affording evidence of the structural value of these

bars, and it is to be greatly desired that similar observations should be made on all kinds of modern metallic structural materials. The mild bars to which Dr. Siemens' table refers shows a mean elastic limit of 17.37 tons when annealed, though the same bars showed the lower mean elastic limit of 16.62 before being annealed, and curiously the elastic extension is also greater in the annealed bars, the mean extension in bars 5 feet 0 inch, and 4 feet 11 inches, being 0.086 inches, the value of the Te of the bars being by the before-mentioned formulæ, respectively 57.04 and 53.348. This denotes a high structural value, although this indication must be taken with the value of Tr which cannot be gained from the table referred to. Such materiall, however, is not to be had or cannot be safely used in plates, and even in bars has been very little used in bridgework. Steelmakers have yet to satisfy engineers that it can be safely used.

The most of the recorded experimental results of tests of mild steels do not give the extension of the elastic limit, so comparisons with other materials cannot at present be made. From what has been said, however, it will have been seen, that it is very necessary that these figures should be obtained, and what has often been observed may be here repeated, namely, that in order to the production of a satisfactory series of tables of the mechanical properties of different structural metals, experiments should be conducted on a uniform basis, and with uniform lengths of tests pieces, or if not of uniform length, they should be of a minimum length of either ten inches or one foot.

Such experiments would be perhaps costly, but there is at least one wealthy engineering society, by a committee of which such experiments might be usefully carried out on the structural materials of to-day.

In conclusion, a few words may be said upon the behavior of the harder kinds of steel plates in which they differ from those of iron. It has been observed by many that some of the steel plates with an elastic strength as high as 18 tons per square inch combined with a ductile extension as high as 15 per cent., as obtained by the tests of strips of such plates, that in the hands of plate smiths or when built into structures, they behave very differently to iron with the same apparent mechanical properties. The toughness of good iron plates enables them gradually to dissipate any internal differential molecular strains of tension and compression that may be resident in them as they leave rolling mills, by differential compression and tension. Steel plates which are comparatively hard, but which, when torn asunder in test-strips, indicate an ultimate extension of as much as 15 per cent., might be expected to do the same. Such, however, is not the case, for the plate has often behaved, when built up into a structure, as though its ultimate extension was not more than one or two per cent., and, like glass, possessed of a high elastic limit, but no toughness. Why this should be is not known, but it may be suggested that such being the behavior, the following may afford some clue to the fact that thick plates, at least of such material, have fractured in various directions, after the structure of which they have formed an integral part has been completed. Most plates before being built into a structure are annealed, but the following remarks apply equally whether annealed or not.

Plates when taken from the rolls or from the annealing oven are generally laid on a flat surface to cool, but whether laid down or stood on edge, cooling takes place somewhat more rapidly towards the corners and edges than at the middle. At first, the whole plate is of the same temperature, which may be that of redness. The exterior parts first assume the rigidity of cold iron, and contraction takes place on the interior parts which remain at a higher temperature, and therefore the contraction has taken place under a tensile strain. Thus, if a plate of 1 inch in thickness is considered in illustration, it will be seen that a corner of, say 6 inches on either edge, has an area on the two sides of 36 square inches, but it has also the additional effective cooling area of the edges, which adds 12 square inches, making for a surface area of 36 square inches a total of 48 square inches of effective cooling area by radiation and evection. If, on the other hand, an area on the two sides at the center of the plate, of 36

square inches of such surface, be taken into consideration, it will be seen that the edge surface can only be considered as cooling by conduction. Thus, the effective cooling area of the outer parts of the plates is much more efficient than the central parts. These outer parts having, then, become rigid and contracted under tension, exert a corresponding compressive strain upon the interior parts still at higher temperature and thus more or less amenable to compression. This tensile strain upon the outer parts or borders of the plate is gradually eliminated as the interior parts cool, and is finally changed into one of compression, as the inner parts contract in cooling under a molecular tensile strain, due to the incapacity of the rigid border to follow the inner parts in their contraction. In the cold plate put into a structure, there is thus initial molecular strain differentiating from compression at the edges to tension towards the center. If the plate is cooled under circumstances inducing unequal cooling these internal strains are aggravated, and they may possibly be of such magnitude that extraneous strains, that would not materially affect a tough iron plate, may be sufficient in a hard steel to cause rupture. Further, when a plate of such a character is being riveted up, every rivet is compressed under a very high strain to make it fill the holes, and thus, acting as a viscous fluid, adds to the strains already tending to destroy the plate.

These remarks are only made as suggestions, and should perhaps have been put in the form of a question, as they are somewhat aside the object of this note, which is to invite discussion on what seems to be the tendency in the production of very mild steel plates, namely, that in the endeavor to remove the difficulties which have attended the use of steel plates of high elastic limit, we seem to be in danger of losing the facilties for producing lighter structures which the application of steel seemed at one time to afford.

THE STRENGTH OF BOILER FLUES.

From "The Engineer."

VERY high pressures are now carried at sea on the outside of tubes of comparatively large size. These tubes are the cylindrical furnaces of marine boilers, and reach in some cases a diameter of 4 ft. It is of the utmost importance that very definite rules should be laid down for the guidance of those who design such furnaces, in order that no mistakes may be made. We say "definite rules," because the whole subject has been fully investigated. There is apparently nothing more to learn about it, and there should, therefore, be no trouble in constructing a simple formula which would enable an engineer to tell, with very little calculation, what is the proper thickness for a furnace tube of any given length and diameter, intended to sustain a stated pressure. Something of the kind will be found in almost all treatises on steam boilers. The practice thirty years ago was to treat the flues as though the pressure were to be exerted inside of it. The pressure was to be found by the well-known rule $p=\frac{2st}{d}$, where s is the strain in pounds per square inch to which the iron is to be subjected, t the thickness of the plate, d the diameter of the boiler, and p the working pressure. Then the proper thickness for flues was half that which would suffice for a shell. This practice is, we are happy to say, no longer followed. It answered fairly well while moderate pressures not exceeding about 45 lbs. on the square inch were used, but it was totally unfit to deal with such pressures as are now carried at sea and on land. Wilson gives the following formula for the strength of flues: $p=\frac{262.4\times t^2}{l\times d}$ where p is the collapsing pressure in pounds per square inch, t the thickness of tube in thirty-seconds of an inch, l the length in feet, and d the diameter in quarter feet;

other rules may be found in other treatises. Fairbairn has shown that the strength of a flue to resist collapsing pressure varies directly as the 2.19 power of the thickness, and inversely as the diameter and length. Thus:

$$P = 33.6 \times (100t)^{2.19} \div L \times d$$

and $$p = 5.6 \times (100t)^{2.19} \div L \times d.$$

These are very ungainly formulæ, and useless without logarithms. It may not be superfluous to say here, however, for the guidance of those who would like to use Fairbairn's rules as a check on their own practice, that in using the formulæ the thickness of the plate is to be multiplied by 100. The log. of the result is to be found and multiplied by 2.19. This gives a log. the natural number of which is the 2.19 power of $100t$.

It is not to be supposed that the Board of Trade, which is so precise in its instructions and rules for marine engine builders, would allow this subject to pass without consideration. Accordingly the Board has proposed a rule, which runs thus: $p = \frac{60{,}000\,t^2}{(l+1) \times d}$. Here 60,000 is a constant for furnace tubes with longitudinal seams, lapped joints, and punched holes, single riveted; l is the length of the furnace in feet; d is the diameter in inches; and p the working pressure. To illustrate the application of this rule, let us suppose that a furnace is 40 inches in diameter and 7 ft. long, and that the plates are .375 inches thick. Then $\frac{60{,}000 \times .140625}{(7+1) \times 40} = 26.3$ lbs. as the working pressure. But the Board of Trade rule is not the only one with which engineers have to deal. "Lloyd's" have a rule also, which is, $p = \frac{89{,}600 \times t^2}{l \times d}$. Applying this rule to the furnace whose dimensions we have just stated, we have $\frac{89{,}600 \times .140625}{7 \times 40} = 45$ lbs. We thus find that one great authority on marine engineering allows nearly twice as great a pressure to be carried as the other. If the Board of Trade be right, then Lloyd's must be wrong, and dangerously wrong. If, on the other hand, Lloyd's are right, then the Board of Trade behaves very vexatiously and insists on a much lower pressure being carried than is necessary. Before any opinion on this point can be properly pronounced it is necessary to call in some other authority. Referring to the tables given in Wilson's treatise on steam boilers, we find that the collapsing pressure of a flue 7 ft. long, $\frac{3}{8}$ inch thick, and 40 inches in diameter is nearly 400 lbs. on the square inch. Lloyd's factor of safety is consequently about 9 to 1, while the Board of Trade factor is nearly 15 to 1. If one margin be enough then the other must be too great.. In dealing with this part of the question we can only arrive at anything like a satisfactory conclusion by resorting to the result of experiment. Mr. Wilson's figures refer to very perfect tubes, such as may or may not be met with in practice. Mr. D. K. Clark has investigated many cases of collapsed tubes, and he has prepared the following formula:

$$p = t^3 \times \left(\frac{50{,}000}{d} - 500\right).$$

Applying this rule to the case stated, we have 105.4 lbs. as the collapsing pressure. In this case the Board of Trade factor of safety is nearly 4 to 1, and Lloyd's factor is a little over 2 to 1. It must be remembered, however, that Mr. Clark's rule applies to flues of considerable length without any strengthening rings; to these he has attached no precise value. But it may be taken for granted that a marine boiler furnace tube well secured at each end and not more than a few feet long, is very much better able to stand up against a collapsing strain than a tube 25 ft. or 30 ft. long. We may, we believe, take a mean between Mr. Wilson s figures and Mr. Clark's, and assume that the collapsing pressure of our tube would be about 200 lbs. on the square inch. Under these circumstances Lloyd's formula gives a factor of safety of 4.4 to 1, while the Board of Trade rule gives 7.7.

Now, it is evident that the disparity between the rules of the Board of Trade and of Lloyd's ought not to exist. It places engineers and shipowners alike in a very unpleasant position, and will some day cause a good deal of trouble. A case may be cited which recently occurred. Two wing furnaces on board a

North-county steamer collapsed with 20 lbs. of steam pressure and plenty of water. The collapsed flues are round topped, with flat stayed sides, and by the Board of Trade rules, the working pressure was 22 lbs. and by Lloyd's 42 lbs. It is probable that when the case comes to be investigated it will be found that the metal was either over-heated by the presence of deposit, or that the flues were worn. Be this as it may, it is not inconceivable that the engineers of the Board of Trade and those of Lloyd's may some day come into collision in a court of law over such questions, and we shall then have anything but an edifying spectacle presented for consideration.

The engineers of a great public department asserting that a boiler is strong enough, while those of the Government assert that it is too weak, will not be a satisfactory display in any sense of the word. The question at issue is one really of very great importance to engineers and shipowners. Is it too much to ask in the interests of common sense that the two bodies should put themselves in communication and agree on so apparently simple a matter as the preparation of a rule for the thickness of furnace tubes?

INFLUENCE OF TEMPERATURE IN TUNNELING THROUGH HIGH MOUNTAINS.

By DR. F. M. STAPFF.

Translated from Revue universelle des Mines, for Abstracts of Institution of Civil Engineers.

As the difficulties encountered from elevated temperature in tunneling through high mountains require the adoption of appliances and resources very different from those hitherto employed, the author, as Engineering Geologist of the St. Gothard Tunnel, Airolo, has during the past six years been collecting voluminous materials for the purpose of endeavoring to solve the two following questions:

1st. What is the highest temperature at which men can work underground?

2nd. At what depth below surface is this temperature likely to be reached in tunneling?

I.—*Temperature at which underground work becomes impossible.*—The limit of heat at which men can work depends upon the length of their exposure to it, the amount of exertion they put forth, their acclimatization, the nature of the atmosphere, and, most of all, its degree of moisture. Omitting instances of momentary exposure to exceptional heat, it is certain that men cannot accustom themselves to stand for any length of time more than 60° to 75° Centigrade or 140° to 165° Fahrenheit, even when keeping perfectly still and in quite pure air. In the author's experience on mining and railway works in Mexico and the south of the United States the temperature was as high as 40° C. or 104° F. In tropical seas the temperature in the stoke-holes of steamers occasionally reaches even 69° C. or 156° F., and is aggravated by the dust raised in the act of stoking. Unfortunately there is not sufficient information at present available as to the practicable limits of temperature in underground workings. In upcast shafts used for winding, and for raising and lowering the men, a temperature of from 27° to 32° C. or 80° to 90° F. is allowed for the air current in English collieries; and in Belgian from 22½° to 34½° C. or 72° to 94° F. At Fahlun copper mine in Sweden, in reopening some old workings that had been stopped by a fire twenty years previously, the clearing up was done at a temperature as high as 52° C or 125° F.; but there the natural ventilation was excellent. In another mine, stoping was abandoned at a temperature of 33° C. or 91° F., where the dust from the decomposed pyrites was more intoler-

able than the mere heat, and dyed the miners as black as ink.* The highest temperature observed in the Mont Cenis tunnel was 30° C. or 86° F., at about 4 miles in from the south end. In the St. Gothard tunnel full work was carried on at about 31° C. or 87° F. on the south (Airolo) side, in air surcharged with moisture; and on the north (Göschenen) side at 29° C. or 84° F., in an atmosphere not quite saturated. The author gives detailed particulars of the air-supply to each end of the tunnel, and of the number of men, animals, and lamps consuming it; and on the assumption that the dryness of the air is of equal importance with its purity, he deduces the ratio of 4 to 3 as about representing the superior ventilation of the northern section over the southern at the time of his observations, when each end had been driven about 4 miles in.

According to Professor Dubois-Reymond of Berlin, men can stand 50° C. or 122° F. when the air is as dry as possible, as in the case of blast-furnace workers; but in an atmosphere saturated with moisture even 40° C. or 104° F. would almost certainly prove fatal. Air feels very dry when only one quarter saturated, but becomes stifling before complete saturation is reached; hence a slight diminution of moisture may be of the utmost value, and the principal means of rendering high temperatures endurable would consist in drying the air. A wagon-load of quicklime, notwithstanding the heat evolved in quenching, he considers would even give a fresher feeling than one of ice, on account of the latter rendering the air still more moist. If at the working place there were both a wagon of lime and one of ice, and also a supply of fresh air direct from the tunnel mouth, he is of opinion that work could be carried on even where the temperature of the rock was as high as 50° C. or 122° F. The ice would indeed be far more efficacious if covered with a layer of common salt, whereby not only would the temperature be still further lowered, but also increase of moisture would be prevented. The men would have to work short shifts, and the heat of the body should not reach 40° C. or 104° F., the ordinary bodily temperature being from 36¾° to 38° C. or 98° to 100° F.

The Author goes minutely into the effects observed to be produced upon the health of the men employed in the St. Gothard tunnel. He also reports at length a number of observations he made, as to how hot the men got, and how much work they could do, according to the state of the air in the tunnel. The diminished effort instinctively exerted by them, in proportion as they get hotter from the heat and badness of the air they breathe in such situations, is shown to be in accordance with physiological principles. Taking as the unit of bodily exertion the amount of effort put forth in merely walking along the tunnel at an easy pace—say about 4,550 foot-lbs. per minute—the Author considers this is somewhat exceeded by the ordinary exertion of the workmen employed in the roomier portions of the tunnel, behind the advanced heading. Those engaged, however, in loading the broken rock into the wagons near the forebreast, in the confined space of the advanced heading itself, must in his opinion, judging from the shorter time they work and the higher rate of their wages, be working about twice as hard; and occasional intermittent efforts may be even four times as great. They have to fill the broken stone into baskets upon long narrow lorries running on temporary rails of 1 foot guage, laid alongside the main rails of 3½ feet guage; the lorries have to be run back by hand through a distance averaging about 80 yards to the main trucks, into which the baskets have then to be emptied. A score of men formed the gang occupied in this heaviest work. The relative cost of the clearing per cubic yard of rock in the two headings is found to be represented by the very same ratio as the absolute moisture of the air in them, namely, 1 to 1.18 in the Göschenen and Airolo ends respectively.

The highest limit theoretically possible for the air temperature in tunnel workings would be such as would induce fever

*In the last working of the United copper mines in Gwennap, Cornwall, a hot spring of water at 115° F. was met with in the bottom level about 1,800 feet below surface, and the rock was so hot that even with their thick clothing the miners could not lean against it. (See Proceedings Institution of Mechanical Engineers, 1873, p. 110.) In the Comstock silver mines, Nevada, the temperature averages 130° F. at about 2,000 feet below surface, and sometimes reaches 139° F., while in particular places even 157° F. has been observed. (See Transactions American Institute of Mining Engineers, vol. vii., pp. 45-76; and Minutes of Proceedings Institution Civil Engineers, vol. lvii., p. 393).

heat, of 42° C. or 107° F. in the body; while the extreme practicable air temperature, still not free from the certain prospect of impaired health and premature death, would be that under which the heat of the body should not rise above 40° C. or 104° F. The latter limit being applied to the atmospheric conditions affecting the two ends of the St. Gothard tunnel, the Author calculates that the practicable limit of air temperature should not exceed 45¾° C. or 114° F. in the Göschenen end, and 37¾° C. or 100° F. in the Airolo end, for the laborers clearing the advanced headings. He adds, in a tabular form, the corresponding figures for assumed cases both of harder and of easier work than that of removing the spoil from the ends of these particular headings.

II.—*Limit to Depth of Tunnel below Summit of Ridge.*—The scale for increase of temperature with depth, which obtains in mines and bore-holes sunk below level ground, is inapplicable to mountains, owing to the cooling effect of their exposed sloping sides. From Borelli's temperature observations in the southern portion of Mont Cenis tunnel, Ansted deduced an increase of 1° C. per 50 meters, or 1° F. per 91 feet depth below the summit of the mountain profile over the line of the tunnel; but that rate did not hold good for lower elevations in the same profile, and was therefore not applicable as any guide for other tunnels. From his own observations in the St. Gothard tunnel, from 1873 to 1877, for distances of 4,800 yards in from the northern mouth and 4,500 yards in from the southern, the Author deduced empirical formulæ for the temperature to be expected during the further progress of the work. These having been found to hold good for the 2,000 to 3,000 yards next driven, he now reproduces some of the principal. For the temperature of the rock itself, the general average result in its simplest form is an increase of 1° C. per 48.4 meters, or 1° F. per 88.1 feet of vertical depth below the surface of the mountain. This scale gives too low a temperature for parts of the tunnel that are under valleys and plains on the mountain sides, and too high for parts under peaks; the variations from the actual temperatures noted at individual points in the tunnel amount to nearly as much as 5° C. or 9° F. But, for the mean temperature throughout any considerable length of the tunnel, the calculated result agrees exactly with actual observation, however varied be the mountain profile overhead. In confirmation the Author reproduces from the St. Gothard Company's eighth report a Table of observations made in 1878 through 1,500 yards' length of the southern half of the tunnel, between 5,000 and 6,500 yards in from the mouth. The variations of mountain profile may even have the effect of producing a practically uniform temperature for miles of tunnel, notwithstanding hundreds of yards difference in the heights of rock overhead. For the temperatures to be expected at the middle of the tunnel, the minuter calculations are given which had been made last year by the Author, at the time when each end had been driven about 7,700 yards in, leaving then about 1,000 yards intervening to be driven. His estimate, with a margin for error of ± 2½° C. or 4½° F. was 31¾° C. or 89° F. for the rock; the same for the air about 150 yards behind either forebreast, prior to the two drivages holing through into each other; and 33¾° C. or 93° F. for the water issuing from the rock. In March, 1880, after the holing through, the actual mean temperature of the rock for the middle length of 1,000 yards was found to be 30½° C. or 87° F.; and this was also the air temperature 150 yards behind the forebreasts prior to holing through. At the two forebreasts themselves the air temperature was brought down as low as 27¾° C. or 82° F. while boring, and 30° C. or 86° F. while clearing away spoil: which was about 3° C. or 5° F. lower than calculated, the reduction being due to an extra supply of compressed air during the last 1,000 yards' drivage. These several temperatures, though high enough to retard the progress materially in the middle of the tunnel, and render the work more laborious, was not so excessive as to entail either stoppage or danger.

General Remarks.—Having entered minutely, and at great length, into the various conditions affecting the execution of the work in the two ends of the St. Gothard tunnel, the author refrains from attempting to lay down a fixed limit, either of temperature or of depth, for

any future tunneling operations which may enjoy the advantage of resources superior to those hitherto available. But the means to be employed for dealing with higher temperatures than have hitherto been encountered would have to be very carefully matured beforehand, both theoretically and practically.

Projected Simplon Tunnel.—The extent of guidance, furnished by the light of present experience, is illustrated by the author's application of his calculations to the principal projects for tunnelling through the Simplon. Of the longer routes plotted, for piercing the mountain nearest its base, from near Brieg on the northern slope, those of MM. Favre & Clo, and M. Lommel, each nearly 12 miles, would appear to be impracticable of execution with the resources at present available. According to their mountain profiles, the depth of these tunnels below the ridge would be about 7,300 feet; whence the temperatures to be expected midway in the tunnels would be about 47° C. or 116° F. for the rock, and for the air 150 yards behind the forebreast, and about 53° C. or 127° F. for water issuing from the rock. In the shorter and higher tunnel proposed by M. Stockalper, about 10 miles long, piercing the range at about 2,560 feet above sea-level and beneath a rather lower portion of the ridge, the author estimates the depth below the ridge at about 5,900 feet, and the rock temperature midway in the tunnel at about 40° C. or 104° F.; here therefore the extreme limit of practicable execution would be reached. In two still shorter and higher tunnels, each about 7½ miles long, proposed by MM. Clo & Venetz, and M. Jacquemin, the temperature encountered would be much the same as has been met with in the St. Gothard tunnel; but their greater height above sea level would somewhat detract from the value of both these tunnels, as compared with those nearer the foot of the mountain.

Selection of Route.—Supposing its height above sea level be already determined by commercial or political considerations, the route selected for a tunnel should be such as to offer the greatest facilities for its execution. In the case of the St. Gothard tunnel, it was pointed out by the author in 1877 that, if the route had lain 1 mile or 1½ miles westward, it would have been attended with several advantages, which he here recapitulates. It is not so easy from surface indications to form an idea about the quantity of water likely to be met with, and the solidity of the rock to be driven through, as it is from the height and contour of a mountain to calculate the increase of temperature likely to be encountered. The principles long established by general mining experience may, however, be properly applied to tunneling; and in the longitudinal sections compiled by the author for the St. Gothard tunnel, it is seen how the surface indications held good down to that depth: fissures, slides, and faults, noted on the mountain profile, severally made their appearance without fail in the tunnel, most of them in a very unwelcome manner. A recent illustration from near the middle of the tunnel is cited. The author thinks it safer and easier to avoid difficulties of this sort by careful selection of route beforehand, than to try to get over them afterwards during the execution of the work. For the projected Arlberg tunnel in Austria, he is glad to find the route laid down with a view to avoiding, by a curved course, rock that seems likely to let out streams of water. Tunnels through high mountains should, as far as possible, be driven in places where they will have the least height and bulk of mountain overhead, and where they will be likely to be most free of water.

Mode of Driving.—The mode adopted for driving the St. Gothard tunnel is not considered by the author, from the experience there gained, to be the most eligible for long tunnels, where not more than two ends can be driven, and these not faster than a certain limit of speed, and where it is impossible to foresee all the difficulties that may arise. In respect of the atmosphere pervading the working places, that mode of driving seems indeed decidedly objectionable. In the St. Gothard tunnel the long succession of trenches and steps, by which the small advanced heading was gradually widened and deepened to the full size of the finished tunnel, caused the working places to stretch back as far as a couple of miles behind the forebreast. Hence, even admitting the practicability of artificially supplying the advance heading itself with air so cold that, where the rock tempera-

ture was from 40° to 50° C. or 100° to 120° F., the men could work a hundred yards behind the forebreast, the author considers the same means would be altogether inadequate for such a length as a couple of miles of tunnel, full of men at work and smoke from blasting. Moreover, in the usual plan of driving the advance heading along the crown of the tunnel, the water issuing from the forebreast has to flow all along the heading, and then down along all the following steps and trenches of the successive enlargements, before reaching the completed culvert in the finished portion of the tunnel. The author therefore suggests the desirability of proceeding by an inverted method, somewhat as in metalliferous mines: driving the advanced heading along the very bottom of the tunnel, and carrying the culvert forwards promptly with it, so that all water should drain at once into a narrow channel, presenting small surface for evaporation. Less moisture would thereby be imparted to the air, even when driving through very wet rock, than is evolved in drier rock, from the vast extent of wet surface exposed by the puddles and mud that are inevitable with the ordinary mode of driving. Such an inverted method would doubtless present difficulties in regard to ventilation; but more attention might advantageously be paid in tunneling to the improvements that have already been realised in mine ventilation by the adoption of systematic arrangements. For long tunnels that will take years to execute, instead of improvising foul-air outlets temporarily and at random, or opening cocks here and there on the compressed-air main, a regular system of ventilation should be carried out by means of brattices, air-doors and trunks, and should be pushed forward continuously to follow up the progress of the work. A further suggestion for facilitating the execution of tunnels through hot rock is to complete each end to the full size as far in from the mouth as can be done without the heat becoming too oppressive, say up to 30° C. or 86° F.; and then to push forward and complete the advance heading alone, without continuing the work of enlarging behind it. The practical difficulty would then be reduced to the efficient ventilation of the heading for a length of 100 yards back from the forebreast. As soon as the two headings met, a good current could be established right through from one end of the tunnel to the other, which would be largely efficacious in keeping down the temperature at the working places, during the subsequent enlargement of the central length.

Haulage.—Manual or animal labor in the working places should as far as possible be replaced by mechanical power; though how to manage this practically for the most fatiguing portion of the work—the clearing away of the spoil—yet remains to be found out. Endless-rope hauling, as already carried out at collieries, would be more convenient for removing the stuff than the use of compressed-air locomotives, the size of which prevents their penetrating so far into the advancing end, and also interferes more with the ventilation.

Artificial Cooling.—This is the most difficult question of all, and is by no means solved by the use of extensive appliances for supplying compressed air. The heat from the rock is practically inexhaustible; and, whether all the air-cocks at the forebreast are open, or all shut, the air temperature 200 yards back is practically constant and equal to that of the rock, and thenceforth gradually rises as the air travels further back along the working places. The utmost cooling at the forebreast, while four rock-drills are working together and discharging their exhaust air at 2½ to 4 atmospheres pressure, does not exceed 4° C. or 7° F. at most, the average being only 1° C. or 2° F. below the rock temperature; and during the clearing away of the spoil the air may rise as high as 4° C. or 7° F. above the rock temperature, the average being 1½° C. or 3° F. above. A table is given of periodical observations made by the author at both ends of the St. Gothard tunnel while the drivage was suspended for surveying the line of driving, the working places being then deserted and the air cocks left open. These records show that with a rock temperature of 47° C. or 116° F. it would be no easy matter to keep the air down to 35° C. or 95° F. in the working places while work was being carried on. There is no great difficulty in delivering highly compressed air in large quantities at the forebreast; the difficulty lies in arranging its distri-

bution. Men cannot work within a distance of 5 or 6 yards in front of an aperture not more than 4 inches diameter; and often put a basket over it to break the blast. The most serious obstacle to the use of compressed air, as the sole means of cooling, lies in the low specific heat of air, whereby vast volumes become heated immediately to the temperature of the rock, without perceptibly cooling the rock itself. A jet of cold water has very little cooling effect on the air, and the mist thereby produced is decidedly objectionable; on the contrary, indeed, the compressed air should itself be supplied as dry as possible. To cool the air before delivering it into the tunnel is of little use, because its cooling effect depends much more on its sudden expansion; and also because, however cold it may have been at the tunnel mouth, by the time it reaches the inner end of a very long main, the air is found to have acquired within 2° to 3° C. or 4° to 5° F. as high a temperature as the surrounding atmosphere in the tunnel. As a means of cooling in combination with other plans, the adoption of compressed air points to the use of compressing apparatus on a much larger scale than that at either Mont Cenis or St. Gothard. A further problem will be to devise better methods for drying the air. The air reservoirs at Mont Cenis and St. Gothard answered the purpose to a certain extent, and were supplemented by additional appliances at St. Gothard. For completely drying the air, Professor Dubois-Reymond's suggestion to employ quicklime might be adopted; and the author points out that this mode of drying would be more efficaciously applied to the compressed air before its delivery into the tunnel, than by conveying the lime itself to the working places. The cooling mixture of ice and salt should, however, be conveyed in the spoil-wagons to the working places, and there discharged on the off side; as it gradually melted away, the water would run off, but without imparting so much moisture to the air as if there were no salt mixed with it. The combination of these two plans appears to the author to offer the best means of enabling tunnels to be driven at high temperatures.

Workmen and Shifts.—Italians, used to a warm climate, and taking to mining with skill and perseverance, form as valuable a class of workmen for European tunnels as the Indians of Mexico or South America for tunneling operations in those countries. Under such circumstances as obtained in the St. Gothard tunnel, the author considers that, having regard both to economy and to health, the average duration of shift should not exceed eight hours. Two hours must be allowed for walking in to the working places, when at a distance of 4 to 4½ miles in from the mouth; then some rest is needed before commencing work; and two to three hours' work is all that can be managed before starting on the two hours' return journey, which should also be made leisurely on foot. The men at the boring machines, and those clearing away spoil just behind, having the coolest and driest air, often remained fourteen hours in the St. Gothard tunnel. The men should strip themselves of clothing as far as possible, so long as the air temperature is lower than that of the body; if ever tunneling came to be done at a higher temperature, it would of course be desirable to work with clothes on. Wherever artificial cooling of the air is required, the working places should also be followed up closely by suitable refuges or chambers, fresh and well ventilated, and even filled with dry air at a slight excess of pressure, where any one overcome with exhaustion can be promptly restored, and where the men can dry and change before leaving work. Cooling beverages are recommended, for avoiding the danger of drinking too much cold water while at work.

In conclusion the author points out that, from the nature of the work in long tunnels under high mountains and through hot rock, the question of cost, and even of time, may often become a consideration of secondary importance.

HEIGHT OF WAVES.—From the result of ten thousand observations, it appears that the cubes of the heights are proportional to the squares of the velocities of the winds. A wave of 2.20 meters in height corresponds, according to the author, with a wind of 5 meters per second velocity; and as the relation $(2.20^{m})^{3} = x\,(5)^{2}$, $\therefore\ x = 0.426$, and consequently $(2\,H)^{3} = 0.426\,v^{2}$. Hence 2 H, the total height of the wave, $= 0.75\,v^{\frac{2}{3}}$.

AN ADAPTATION OF BESSEMER PLANT TO THE BASIC PROCESS.

By A. L. HOLLEY, Memb. Inst. C. E., &c.

From Papers of the American Society of Mechanical Engineers.

THE maintenance of refractory linings in Bessemer converters, in such a way as to promote regular and maximum production, has been the subject of more experimenting than any other feature of the Bessemer system, and it is still the least perfect and satisfactory feature, excepting perhaps the casting of steel. Linings are not only eroded by the mechanical action of the charge, but they are chemically decomposed by its various slags. The silica linings usually employed have, indeed, been so improved, that an average of say 60 charges per 24 hours can be got out of a pair of converters, and the shifting of interchangeable converter bottoms (containing the tuyeres) is so rapid that it does not delay production; but the repairing of the fixed lining just above the tuyeres, where both mechanical and chemical action are most severe, is frequently the cause of delay, and the operation rapidly performed between heats is tedious and costly. The accumulations of slag on other parts of the lining must also be quarried out, else the converter will become too small for the charge.

These are the conditions of maintaining silica linings; but the difficulties are increased, probably about threefold, when the linings are made of lime, for the basic process. The basic process consists in removing phosphorus from the iron under treatment, by retaining the phosphorus oxidized by the blast, in a basic slag formed of say 20 per cent. of lime added to the charge. An acid (silica) lining would vitiate the basic slag, and would also be rapidly destroyed by it. Lime containing some magnesia, and produced by burning magnesian limestone (dolomite), is at present the only basic material successfully used for converter linings. It is usually made into bricks, which are hard-burned and built up with mortar of similar material to form the lining.

Basic bottoms and tuyeres stand ten to fifteen charges, nearly equaling acid bottoms, and they may be readily changed; but basic linings, near the tuyeres, and also in other parts where abrasion is severe, wear rapidly and must be frequently repaired by cooling the converter and inserting new bricks, or patching in some suitable manner. The converter is thus put out of use for at least twenty-four hours—a very serious delay to production. From a wide observation the author feels safe in saying that a basic lining is rarely run above 60 charges without extensive repairs, and in some works repairs are made every time a bottom is set. With some irons there is also an accumulation of slag around the mouth of the converter; its removal sometimes also causes delay.

The output of a pair of converters in Europe averages about half that of a pair of converters of the same size in the United States, and is often less than half. The limited endurance of basic linings in Europe is therefore a less conspicuous defect than it is here, where one converter must make 25 or 30 charges in 24 hours, so that the repairs of basic linings, as at present conducted, would keep an American plant idle about half the time. This delay is really as important in Europe as it is here; the greater the output from a given plant, the cheaper the product.* In order, therefore, that the basic process may come into extensive use, basic linings must be so maintained that their output will nearly equal that of acid linings.

There are two reasonable conditions of improvement; the one is to prolong the endurance of basic materials, so that their repairs can be made with little de-

* The statement sometimes made in England that the rapid production in America impairs quality of product, is but a cover for inadequate plant. Steel is obviously no better because five hours instead of one are consumed in setting a vessel bottom, or because it may take twice as long in an English works to handle materials and product.

lay, while the converter is in position for use. There seems to be little or no progress, or probability of immediate progress in this direction. The other is the rapid and complete removal of a worn lining and the replacement of a repaired one. A third system, seriously proposed, is to double or treble the entire converting plant. The only practicable way to replace a refractory lining (which cannot be handled by itself) is to replace the vessel which contains it. The worn portions of the lining may thus be repaired at leisure, in another part of the works, rather than in position for use, where repairs would retard output.

An obvious way to replace an entire converter lining is to replace the entire converter. This system is already under construction in Europe. The method is also obvious—lifting the converter bodily out of its pillow-blocks, and conveying it to the repair shed by means of an overhead traveler; then setting a repaired converter in place by the same means. Such a plant is doubtless cheaper than a duplicate plant, and its output should be materially greater than that of fixed converters. But the operation of changing an entire converter must be slow and tedious. When the arrangement is such that pillow-block caps are required, these must be loosened by unscrewing heavy nuts; then they must be made fast to the crane chain, lifted, traversed, and set down. The blast pipe connection must be broken, and possibly some platforms must be removed. Then the traveler is placed exactly centrally over the converter, ponderous chains are made fast, the mass is raised high enough to clear surrounding parts, and drawn laterally to the repair shed; then the converter is placed centrally over its seat and lowered and steadied (as it swings from a chain) into its pillow-blocks. The repaired converter is raised, traversed, and set in place by repeating all these operations; the blast connexion is then made, and the pillow-block caps are lifted, traversed, steadied into place, and screwed down. If the converter is removed in sections, transferring each section and making the refractory joints will occupy much more time. The chimneys and the openings in the side of the building must be high enough to make passage not only for the traveler but for the converter when lifted out of its seat, and for the chains that sustain it. A traveler of the required power, height, and length is obviously a ponderous and costly structure, and in work with reasonable speed it must have independent steam power—the hydraulic system of the works cannot well reach it.

The method of replacing the lining proposed by the author and shown in the engravings is *removing only the shell* of the converter, lowering it out of the trunnion ring easily and rapidly, by means of a simple lift and car, and replacing a repaired shell by the same means. No pillow-block caps, blast connexions, nor other surrounding parts are touched; a dozen cotters are knocked out, the shell is lowered and run straight back to the repair shed, the new shell is run in, lifted, and cottered on; this is all, The machinery and transference are on the general level, and not 40 ft. or more up in the air. The car may be moved by a small reversing engine or by a hydraulic capstan, by means of a wire rope and sheaves suitably arranged. The car runs against a stop, and the lift is perfectly vertical, so that the shell may be put in place by two rapid motions without the delay of adjustment.

The lining may be heated before the shell is put in place, and bottoms (and tuyeres) may be separately removed, as at present, or they may be taken away with the shell and repaired without removal from it. In the latter case, the shell must be placed in trunnions, in the repair shed, so that the bottom may be turned downward for repairs. But if the bottom is first removed, the shell need not be placed in trunnions in the repair shed; the shell will stand mouth downward on the car, a position most favorable for repairing both the mouth and the lining about the tuyeres, which are the two places chiefly needing repairs. This is doubtless the better plan, and it saves the cost of supplementary trunnion rings and turning gear. The diagrams show the converter hung so high above the general level that the bottom and tuyere box can be hauled out, with the shell, under the trunnion ring. In case the bottom is previously removed, the converter may be hung some 3 ft. lower.

It has been remarked that in American works converter bottoms are changed so

rapidly that one is always ready, even when tuyeres stand but eight or ten operations. Changing converter shells is much more rapid than changing bottoms. The several operations of removal and transportation are the same, but the converter lining must be trimmed out to receive the new bottom, and a refractory joint must be made. The new shell has merely to be cottered on.

The comparative cheapness of apparatus to change the shell, instead of the entire converter, is obvious. The two hydraulic lifts for removing the bottoms are made heavier, and there are several cars of simple construction; this is the entire extra apparatus. The increased cost of the converters is not important. In the other case the traveler, with its engine and the standards and turning gear in the repair shed, and the trunnion rings and pinions (the chief cost of the converters) for each spare shell approach in expense that of a duplicate plant complete.

But one objection has been raised, as far as the author is aware, to the plan proposed, and that is the possibility of damage to the lift under the converter, in case the charge should burn through and fall upon it. To avoid such damage, the lift table may be sunk several inches below the pit level and covered with sand. It may be remarked that lifts under converters are used in nearly all the American works with satisfactory results.

The engravings illustrate the construction and arrangement so fully that little explanation is required. The trunnion ring is of cast iron with an inch wrought iron lining; or it may better be a steel casting, which will not require a lining. There is a 2-inch annular space between the trunnion ring and the converter shell, and the shell is prevented from shifting laterally by means of the wedges. The car is raised by the lift to receive the shell; or the shell may be lowered by means of a fork on the lift passing through the car.

This construction of converters has led the way to a general improvement in the design of the plant. The shells and bottoms may be run out laterally into the converting house, but the space here is insufficient for convenient repairs, and the shells for one converter could not be well got to the other. In order that there may be one common place for repairs, and ample room both for spare shells and spare bottoms, they must be run out in rear of the converters. If blast furnace metal is brought directly to the converters, this rear space is not otherwise wanted; but if cupolas are placed there, as is usually the case, they must be so arranged that the shells can pass out under them.

But the cupolas (excepting the spiegel cupolas) may best be placed elsewhere; if there are blast furnaces, the cupolas may be so arranged near them, as to utilize the same system of transportation, hoisting, blowing, and hot blast. There should be plenty of spare gas from good furnaces to heat cupola blast. These are very important considerations, regarding both cost of plant and economy of working. And judging from the experience at many works, the disadvantages of hauling fluid iron some thousands of feet in a railway ladle, are less than those due to crowding the melting department and its stock yard and appurtenances, close behind the converters. Fluid iron is hauled from one to two miles * without chilling: it need usually be hauled but a few hundred feet; and the cost of the transporting plant and service should be about the same for the two systems. There are two important advantages in the arrangement.

1. Placing only the spiegel cupolas, instead of the entire melting department, close behind the converting house, leaves its rear comparatively open to free ventilation, thus cooling not only the space around the converters, but also the casting pit.

2. This arrangement provides ample room for the convenient removal of slag, which in the basic process is very voluminous; one long dumping car placed under both the converter and the ladle catches it all, and as the bottom of the pit is on the general level, the slag is neither handled nor lifted—the car is simply hauled out by the yard locomotive and dumped. Experts well know the cost and inconvenience of breaking up and quenching slag in the pit, and of lifting it out of the pit and then loading and removing it.

Iron may be got to the converters in

* At the Barrow Works it is hauled two miles, at Ebbw Vale some five miles.

a ladle by various means. It may be hauled on the general level, to one or more hoists, and run into short spouts or directly into the converter mouths, or it may be drawn up a gradual incline, or lifted by a hoist to an elevated railway near the converters, and thence tipped or tapped into them directly or through spouts. The short elevated railway has one conspicuous advantage—it is out of the way of all other apparatus and operations; it does not cross railways, nor interfere with any transportation on the general level. This is an important feature when a charge is made every 20 to 30 minutes. The ladle may be run to the converter mouth* by various means, so as to tip directly into it, but the application of power to the transportation is awkward and difficult, so that there is more or less delay. The ladle is drawn by a locomotive to short, steep spouts leading to the converters; there is no lateral nor hand movement, and hence no delay. A spout leads to each converter, chiefly for the purpose of leaving the space between the converters (where the common spout is usually placed) quite free for the spiegel ladle.

The spiegel cupolas and their appurtenances occupy so little room that they are placed, without interference with other apparatus, very near and above the converters. A railway ladle receives the spiegel from either cupola and tips it directly into the converter quickly, and hence completely, by a short run and without hoisting or lateral movement. It may be weighed in transit if desired. The wide platform between the converters is at other times free for bringing lime, scrap, or other materials to the converter mouths, and these materials are conveniently raised by the cupola hoist.

The floor of the converting house is raised a few feet, so that the pit bottom may be on the general level, for the convenient removal of slag, as before explained. The ground outside of the converting house slopes gradually to the general level; this facilitates the removal of products, and also the drainage.

The plant for repairing shells consists of two turntables, some short railways, and a shed, also some platforms, and a lift for materials. If bottoms are to be removed with the shells, there must also be mounted trunnion rings and turning gear, also a crane, in the shed; but, as before explained, this seems unnecessary. Room is shown for repairing four shells at a time, but the railways may be lengthened to accommodate more. The plant for repairing bottoms consists of short railways and turn-tables, a space for ramming bottoms under a shed, and the necessary ovens for drying them; also a crane which sets the bottoms directly on the oven cars. If tuyeres of ordinary size are used, fewer ovens are required; if the bottom is all one tuyere, rammed around rods, it must be burned for two or three days, so that more and hotter ovens are necessary. The repairing department may obviously be arranged in other ways, to suit special cases.

The average output of the American plant, having two 6-ton to 7-ton silica-lined converters in one pit, is 100,000 tons of ingots per year. It will doubtless appear that the plant under consideration should produce more with basic linings, because it has 10-ton converters, and means of keeping one of them in constant repair, so that the converting operations may fellow one another without interruption.

Recapitulation.—1. The endurance of basic linings is so small that the ordinary system of repairs would reduce the output of an American plant about one-half.

2. The only adequate system of repairs, with existing basic refractory materials, is to remove and replace linings bodily by removing and replacing the vessels containing them.

3. Changing converters, trunnions and all, requires very costly apparatus, and much labor and time in disconnecting parts, and in making the transference.

4. Changing only the shells of converters (leaving the trunnions and their connexions undisturbed) requires only cheap and simple apparatus; and the operation may be performed so quickly that basic linings will give the maximum output of acid linings.

5. Leaving the building open in rear of the converters, instead of placing the melting department there, gives good ventilation and ample space for bottoms and shells to be run out for repairs, and for slag to be removed from the pit. The cupolas (excepting the spiegel cupolas) may be placed elsewhere, especially

* As at the works of Bolckow, Vaughan & Co.

by adjacent blast furnaces: and melted metal may be transported thousands of feet without difficulty.

6. Placing the pit bottom on the general level allows slag to be hauled away directly, without rehandling or lifting. The elevation of the converting house floor, thus produced, facilitates the removal of products.

7. The metal ladles are brought in behind and above the converters, and discharged by spouts, in order to avoid the delay of getting them to the converter mouths; and two spouts are used, so as to leave the space between the converters open for a short run of the spiegel ladle, and of lime and other solid materials to be charged.

8. The spiegel cupolas are placed near and above the converters, so that the metal may be run in quickly and completely, without vertical or lateral movement, by means of a ladle car.

9. The repairing plant is conveniently placed in rear of the converting house, but it may obviously be modified in extent and position to suit local circumstances.

EXPERIENCES WITH ASPHALT.

From Selected Papers of the Institution of Civil Engineers.*

II.

With reference to the objection to asphalt, on the ground of slipperiness, the remedy was to be found in good scavenging. Mr. Delano had received a letter from the manager of the omnibus company in Paris (a company possessing twelve thousand horses and a large number of vehicles) recommending the Charlier system of shoeing, which was well known in England amongst veterinary surgeons and road makers. If asphalt could be employed in the courts and narrow roadways of large cities, where so many poor children were poisoned by the vitiated air and filth, he believed the result would be very advantageous. He hoped that analyses would be made of the air over asphalt roadways as compared with roadways laid with sets. The scavenging in London was very bad, and a person coming to the metropolis, after an absence of some years, could not help noticing it. He was surprised to see the roadway in front of Buckingham Palace in a vile condition. Of course, as asphalt was impermeable, it had to be cleansed, there being no deodorizing principle in it, as partially existed in macadam, before saturation. It would be observed that no remarks had been made as to the comparative cost of asphalt and macadam. In Paris it was rather difficult to get the information, but he had ascertained that the cost price of macadam, including steam rolling, was 6 francs 30 centimes per square meter. The maintenance, however, of a macadamized road might reach the enormous sum of 17 francs per square meter per annum; that was the case in such places as the Champs Elysées and the Rue Royale, where there was a heavy traffic. But the cost of macadam did not end there; it formed banks in the river, and at present steam dredging was employed to remove the banks of sand in front of the drains in Paris. He had a report by M. Vauthier, civil engineer, and a member of the Municipal Council of Paris, from which it appeared that the maximum cost of granite was 22 francs per square meter. The mean cost of the Paris roadways, extending over 6,000,000 square meters, was 17 francs, the mean cost of their maintenance being 1 franc, not including scavenging nor interest upon outlay in any case. In narrow, crowded thoroughfares, the cost of maintenance was, he believed, 3¼ or 4 francs. The chairman of the Paris Cab Company stated that the traction on asphalt was much less than on any other system of roadway. The manager of the Omnibus Company corroborated this opinion, and considered that the wear and tear of carriages, horses, harness, &c., was much less on asphalt roads than on any other. With regard to the

* Abstract of the Discussion following a Paper on Asphalt, by Mr. Delano, published in Van Nostrand's Magazine for December, 1880.

Seyssel and Val de Travers mines, of which drawings had been sent, he might mention that they contained marine shells and shark's teeth, as well as fresh water shells.

Mr. E. B. Ellice-Clark had, a short time ago, taken a good deal of trouble to ascertain the cost of different kinds of paving. He had taken Mr. Deacon's figures for the wood paving in Liverpool, believing that they were the only reliable figures ever published, and reduced them with the other calculations to the standard of 100,000 tons per annum per yard of width, with the result shown in the following table:

—	Original cost per square yard.	Annual Outlay.					
		Interest.	Sinking Fund 3 per cent. compound interest.	Maintenance.	Scavenging.	Gravel.	Total.
	s. *d.*	*d.*	*d.*	*s.* *d.*	*s.* *d.*	*d.*	*s.* *d.*
Wood pavement	15 1.5	7.5	10.1	0 1.0	0 2.7	5.0	2 2.3
Val de Travers compressed asphalt	18 0.0	9.7	..	0 3.6	0 0.4	..	1 1.7
Granite sets, 7 inches × 3 inches laid over a layer of 12 inches of cement concrete	17 9.0	9.6	0.5	0 1.3	0 2.5	..	1 1.9
Macadam in South of England	4 9.0	2.1	..	3 6.0	1 0.0	..	4 8.1

Those figures showed that if the contract entered into by the Val de Travers Company in London could be maintained, their asphalt was cheaper even than granite sets. There could be little question as to the many advantages possessed by asphalt over almost all other materials for road paving. According to his experience, compressed asphalt was the best for roadways. In the City of London, he believed, thirteen or fourteen kinds of asphalt had been tried within the last nine or ten years, and only three of them remained at present in streets with heavy traffic. It was hardly necessary for English engineers to go thoroughly into the chemical part of the question, because all that information had been reduced to practice by the actual wear and tear in the City of London. There were some curious anomalies in the behavior of compressed asphalt to which he desired to refer. He had recently laid a footpath with that material, $\frac{3}{4}$ inch thick. In a short time a large number of cracks appeared, but the path had stood the effects of the last two very severe winters; and, although the cracks were unsightly, they did not appear to have injured the asphalt in the least. He believed the cracks were due, primarily, to the use of a cement not sufficiently purged; the concrete expanded in various directions, and the asphalt followed it, not being sufficiently elastic to extend over the fissures without rupture. Another peculiarity was that in humid weather there was a greater accumulation of dirt on the compressed asphalt than on the mastic. Perhaps the author could state, from his experience in Paris, the reason for that peculiarity. No particulars had been given as to the amount of mud in the streets. Mr. Ellice-Clark had compiled the following table with reference to that point:

Material.	Load of mud for area.	Traffic per annum per yard of width.
	Superficial yards	Tons.
Macadam	344	25,000
Granite sets	500	50,000
Wood	1,666	25,000
Asphalt	4,000	500,000

So that, as dirt meant mud in wet weather and dust in dry weather, asphalt was unquestionably a most economical paving. One of the greatest advantages possessed by asphalt for street paving was the facility with which repairs could be executed.

Cheapside had been laid with asphalt in December 1870, and the roadway had never been blocked a single day for repairs. This alone was an advantage to a city with great street traffic, which could not be said of any other kind of

pavement. It would be hardly possible to overrate the importance of having streets permanently open for traffic. Again the rapidity with which it was originally laid, compared favorably with other materials. In Paris, he believed, a given area of each road had to be opened in eight days; in London, fourteen days had been found ample time to take up the old stones and lay asphalt and concrete, and permit traffic. The author had suggested the use of asphalt concrete costing 80s. per cubic yard; this was too high a price, because a bituminous concrete composed of ballast, coal tar, and creosote oil, could be laid for 21s. per cubic yard, 6 inches in thickness. It had been tried in Liverpool under sets with manifest success. By using a concrete of this kind the work of laying a road could be shortened by the difference in time required for Portland cement concrete to set and that required for bituminous concrete, which was a few hours only; so that a road fit for traffic might be laid in London in eight days. There was no reason why this kind of foundation should not be equal to Portland cement concrete; and it was well worth the attention of municipal engineers and asphalt companies. With regard to foothold for horses, or rather the absence of it, the city engineer had demonstrated, by a series of observations of an exhaustive nature, that saphalt occupied a position between wood and granite, in the order named: and the popular outcry against the slipperiness of asphalt arose from the greater number of horses falling at one time. He was strongly of opinion that the author was correct when he stated that this absence of foothold was due to want of cleanliness. The city corporation had recently put down a number of hydrants all over the city area. If these were utilized in cleansing asphalt, the falls of horses would be reduced considerably The author had made no allusion to the fact that during the past few years the new pavements of Paris in asphalt were much inferior to those formerly laid. It had been asserted that this was owing to the use of the Lobsann asphalt, which did not contain sufficient calcareous matter in the natural rock.

Mr. A. Southam remarked that where it was desirable to lay asphalt on carriage ways, there could be no doubt that compressed asphalt was the best for that purpose. He had paved about 25,000 yards of footway in the parish of Clapham, since 1872. Various small specimens were first laid. Then about 1,000 yards of Barnett's asphalt, 1 inch in thickness, was tried; the cost was 4*s.* 6*d.* per square yard, and it was still in existence, and might be considered a fair path. It was afterwards thought desirable to make the best footpath that could be obtained in asphalt, and, after considerable investigation, the Val de Travers compressed asphalt was selected, and more than 20,000 superficial yards of that material had been laid. A great object was to secure uniformity of paving throughout the district, also facility in executing repairs. It was somewhat unfortunate that transverse cracks had appeared about every 6 or 8 yards. They made their appearance from about three weeks to twelve months after the path was laid. Some of the cracks were cut out, when it was found that corresponding cracks existed in the concrete below. The whole piece was cut out, and new concrete put down, which was kept exposed for six or eight days to harden. Then a thin coating of mastic asphalt was laid over it, previous to the powder being restored. Similar cracks, however, appeared again in the same line, and it was difficult to account for them. He thought to some extent they depended upon the concrete. Great pains were now taken with it, and 6 parts of ballast to one part of cement had been substituted for 8 parts of the former to 1 part of the latter, clean Thames ballast being used; it was mixed with very little water, and was well beaten with shovels. The cement had been tested, and had broken at a pressure of 450 lbs. to the square inch after seven days, during six of which it was laid in water. The concrete for the last piece of paving was kept open for fourteen days, so that it was dry before the powder was laid upon it; the footpath was previously rolled and consolidated; and this path had shown very few cracks. He was inclined to think that compressed asphalt was scarcely so durable as had been generally supposed. The mastic asphalt he believed was somewhat harder, though it was objectionable from

the uncertainty of its mixture, from the difficulty of making the repairs to match the rest of the paving, and from the furnaces for melting it having to be in the street. He had not yet decided whether it was advisable to continue the use of compressed asphalt, or to resort to the mastic. He was surprised at the immense area of footway paving laid in Paris, but the author had not stated of what it was composed. Mr. Southam presumed that was chiefly mastic. The Val de Travers Company had assisted him greatly by their willingness to lay the concrete in any way that might be desired, and to keep it exposed for any length of time. Their manager had suggested that lime concrete would prevent the cracking, and accordingly one line of path had been laid with it. It was not a success; there were no transverse cracks, but it had failed from the settlement of the concrete, which was not yet hard, and had cracked longitudinally from the frost. The concrete in this instance was laid from fourteen to eighteen days before being covered with asphalt. Very few cracks had appeared in the city paths. The foundations were, perhaps, more solid, and owing to the greater traffic brought to bear upon them, the asphalt was more compressed and kept in its place. The asphalt in Clapham had suffered from cracks during the late severe winter, but they had all been longitudinal instead of transverse, and after the frost they had closed and did not look so bad. In this district the use of asphalt would probably be largely extended if a perfect paving could be laid. He would be glad to know which was the best description of asphalt to use for footway paving.

Mr. H. C. Scott observed that, as a director of the Val de Travers Asphalt Company, he might be permitted to refer to their experience of London roadways. The question of cracks upon compressed asphalt footways was one that he frankly confessed had once given them some concern; but they were of opinion that the fault would only last a short time. In going along the Cheapside pathway, which had been laid between three and four years, he had not observed any cracks; and in Moorgate Street, where it had been laid four or five years, there were very few. He had not discovered that the pavement was affected by the humidity of the atmosphere or by rainy weather. They sometimes found, when the drying process had set in, that there was a little streak through the footway, but in a day or two it entirely disappeared. On the grounds of economy, noislessness, and cleanliness, after the many pamphlets that had been written and the many reports presented, there could be no doubt as to the superiority of asphalt; and he believed that compressed asphalt for roadways possessed greater advantages than any other material. The roadway in Cheapside had been laid ten years, and it was still in existence. The heaviest traffic in the world passed over it, but it had never been interrupted for an hour. The repairs were done early in the morning, and the result was that Cheapside possessed a clean, noiseless, and cheap roadway, which, as he knew from the shopkeepers, was regarded as an enormous boon. As to the objection on the grounds of slipperiness, that, as the author had explained, was a question of cleansing, and not a question of asphalt. If engineers and district surveyors would impress upon the Vestries of London the importance of spending more money in cleansing the roadways, they would confer an immense benefit upon the community. The condition of the lanes, slums, and alleys of London was deplorable. The rejected granite sets and York flagging from the richer districts were transported to those localities, where the children of the poor were congregated, and where they played about all day in puddles. If the authorities would only give them asphalt, they would be doing something towards making life tolerable to many who now regarded it as little better than a burden.

Mr. W. B. Lewis asked if any one accustomed to lay asphalt upon concrete had ever tried the plan of laying the concrete in slabs, with joints, in order to prevent cracks. Engineers who had used concrete in large masses were aware that the difficulty of cracks frequently occurred. At the Victoria docks, in one wall 1¼ mile long, and 33 feet or 34 feet high, of solid concrete, there was a hair crack through it at about every 14 feet. He presumed that this arose from the material being homogeneous, and that

there must be expansion and contraction somewhere. Possibly the cracks in the asphalt pavement arose from the concrete being laid in one continuous mass.

It must have yielded somewhere to atmospheric influences, and consequently cracked. If it were laid in slabs, with joints ever so small at intervals, possibly that would get rid of cracks in the asphalt.

Mr. John Knight said that Portland cement concrete expanded and contracted according to the weather, while asphalt, if laid in a mastic state, neither expanded nor contracted, whether ½ inch or 1 inch in thickness. It appeared that the asphalt in Brighton had not cracked because it was in an elastic state, while that laid in Hove in a compressed state had cracked. The reason for the cracking was that it was not of sufficient thickness—only ¾ inch; and the same reason applied to other cases that had been mentioned. No cracks had appeared in Cheapside or in Moorgate Street, because the asphalt had been laid of sufficient thickness—1 inch. Compressed asphalt should not be laid less than that thickness, otherwise it would crack in every direction. The first asphalt of the Val de Travers Company that he had noticed was in a mastic state. It did not last very long; it was not suitable as a mastic asphalt, but as compressed asphalt it was very good. When a surveyor saw a piece of York stone, he could express an opinion as to whether it was good or bad; but he could pass no such opinion with regard to asphalt, whether in a mastic state or compressed. The goodness of the material was only to be ascertained by its durability. The best piece of asphalt in the city was laid in a mastic state in King William Street, eight or nine years ago, and it still existed as when first laid, with the exception of a few repairs for gas and water purposes.

Mr. J. Fogerty observed that he had had some years' experience, both as an architect and as an engineer, in laying pavements and in the use of asphalt and Portland Cement for the covering of roofs and other structures. He did not believe that a layer of ¾ inch of asphalt of any kind was sufficient, especially in footways. The chief cause of cracks was, he thought, to be found in the concrete, and there was only one way to get rid of them—a plan that he adopted ten years ago—never to lay more than nine feet length of concrete at once, bringing straight joints across the footpaths by inserting boards, withdrawing them when the concrete was soft, and leaving the fissures open for a considerable period. The great trouble in getting concrete laid was, to induce the workmen not to use too much water. It could not be laid too dry, especially where it had to be covered with Portland cement or asphalt. A long discussion had recently taken place at the Royal Institute of British Architects on Portland cement and concrete, and it seemed to be the general opinion that one of the chief troubles connected with concrete was the over use of water by workmen. If it was laid almost dry, and thoroughly rammed and jointed at intervals, the joints being left open until the water had evaporated, it might be covered with asphalt without any fear of cracks, provided there was a solid substratum. But where it was laid upon clay difficulties would invariably arise, unless there was interposed between the concrete and the clay a considerable amount of hard, pounded, dry filling for drainage purposes. The most difficult pavements were those laid upon a clay substratum, and he knew of no mode of curing the difficulty except by getting out a considerable depth of clay, and replacing it by dry material. For covering roofs, arches, and the like, he preferred the mastic to the compressed asphalt. For level roadways and footpaths there could be nothing better than the compressed asphalt for pavements, on the ground of cleanliness, but the danger of horses slipping in greasy weather was a serious one. He had often passed through Cheapside in muggy weather and seen several horses down at one time. Whether that could be obviated the did not know. The question had not been fully dealt with in the paper, and he hoped the author would allude to it in his reply. The only remedy that could be suggested was a thorough cleansing, which, so far as Cheapside and similar streets were concerned, could only be done during the hours of traffic by means of numerous hydrants, and the constant use of hose-pipes with large

side apertures, such as those used in Paris, to carry off the washings into drains or reservoirs. Allusion had been made to the operations of gas and water companies which destroyed the roads and pavements in cities. Some twenty years ago, the parish of Marylebone offered a prize for the best section of subway, and it was won by a young student in the engineering class of University College—Mr. Davis. Since that time very few subways had been constructed in London, and even in those, gas and water companies were very unwilling to place their pipes. The only objection he had heard was that the escape of gas in such enclosed places would be dangerous. On that point he should be glad to hear the experience of the city surveyors who had charge of streets and subways in which gas pipes were laid.

Mr. HENRY GLENN attributed the cracks that had occurred in the Val de Travers asphalt to the want of a sufficient quantity of bitumen. Heating the powder drove off the bitumen to a large extent, and if the quantity was reduced, as stated in the paper, to 9½ or 10 per cent., cracks would be sure to occur in severe weather. In the case of mastic asphalt, the difficulty could be obviated, because the cauldron was in the street; and if the asphalt did not contain a sufficient quantity of bitumen, an addition could be easily made to it, and an experienced foreman would know what quantity to add. Some reference had been made to mastic asphalt not wearing so well as other kinds of asphalt. A good deal depended upon the size and quantity of the grit put into it. There ought not to be too much, and the size should not be too large. If it was too large, it would work out, which a small piece of grit would not do. When the Barnett Asphalt Company was in existence, it was the practice to use the large grit, and the consequence was that nearly all their work failed. He had seen concrete laid down in 6 or 7-feet lengths, and allowed to get thoroughly dry at the end; and when the next layer of concrete was put on, it had not been sufficiently wetted and properly jointed. In such a case cracks would arise through the concrete; and if the asphalt did not contain a sufficient quantity of bitumen, it would go through to the surface of the asphalt. He did not agree with those who had said that the concrete should not be laid in long lengths. He thought the more men that were employed, the more quickly the concrete could be laid, and the longer the lengths the better. The work was then all of a piece, and was in the best condition to receive the asphalt.

Mr. E. J. HARRISON had under his control, on behalf of the Val de Travers Company, the majority of the asphalt roadways in the City of London. The history of the compressed roadways in London was soon told. The first laid was that in Threadneedle Street in 1869. It consisted of a layer of two inches of Val de Travers compressed asphalt on a concrete foundation. He had no doubt that many members had noticed it when it was being laid, as it created a great sensation at the time. He remembered looking at it and wondering how many weeks it would last. It was now within two months of being eleven years old, and was still, as it always had been, in good condition. Some new Aberdeen granite had been laid beside it for a trial of endurance, and seven years afterwards it had got into such a state as to require re-dressing and re-setting; but that was not done, because, when the inhabitants of the street learned that the street was going to be closed for repaving, they expressed a preference for an asphalt roadway, which the city authorities gave them. Since 1869 the progress of asphalt roadways throughout London, though rather slow, had been steady. There were now in the city of London alone 12,000 or 14,000 thousand lineal yards of paving, covering a superficial area of 150,000 yards. The Val de Travers Company had upwards of one hundred roads under their charge, many of them being the main thoroughfares of the city, having a concentrated and heavy traffic; and the area would be considerably increased during the present year. One noticeable feature with regard to the use of asphalt was the great number of preparations that had been tried. Between 1870 and 1880 more than fifteen had been employed in London, most of which had proved failures. His Company had already replaced eight or ten of them, not always under favorable cir-

cumstances for the company. In order to shorten as much as possible the time during which the streets were closed for re-paving, the company had generally agreed to lay its asphalt upon the old concrete foundations, some of which had been almost as bad as the asphalt that had been placed upon them, while others had been damaged by the traffic passing over them after the asphalt had worn out. In main thoroughfares like those of London, where every hour's stoppage of the traffic affected not only the occupiers of the particular street, but more or less remotely the traffic of the whole of London, the use of a paving material which required constant renewals or frequent repairs was a serious matter. He certainly could claim on behalf of the Val de Travers Company, that it had never closed a city street for repairs, and such repairs as it had done had never affected the traffic in any appreciable degree. A very little hole, if neglected, speedily became a big hole, and for their own interest, if for no other reason, they had always taken care of the little holes; the repairs, therefore, had been generally done on a small area, rarely exceeding 2 or 3 square yards, and early in the morning before the traffic commenced. The openings for gas and cuttings for water pipes, which were generally a source of great obstruction, were less serious with an asphalt road than with any other paving material. A hole could be cut exactly the size required, and when the work was done it might be made good immediately. Moreover, leakages in mains under an asphalt road were less frequent than under any other material, on account of the absence of vibration. Still those cuttings had to be made, and frequently there was a trifling settlement of the new work, producing hollows and forming puddles, which were more conspicuous on an asphalt surface than on any other; so that he should be glad to see the introduction of subways under the London streets. At the request of the author, he had had small samples of the roadways cut out from some of the oldest roadways having the heaviest traffic, and they were on the table for inspection. Two of them were from Cheapside, ten years old; one was from old Broad Street, and another from Gracechurch Street, nine years old; and one was from the Poultry, a re-lay which was only three years old. The roadway of the Poultry was only three years old, because the houses on the north side were set back several feet three years ago, necessitating an alteration in the footway and roadway. The company laid down new concrete where necessary, and faced up the old, and then spread asphalt on the top of it. They had good weather, and with the assistance of the authorities, and the good will of all the inhabitants, they managed to carry out the work in seventeen days. It had proved very satisfactory, and they had never had occasion since to spend a penny upon it. When Mr. Deacon's Paper on "Street Carriageway Pavements" was read and discussed,* very little was said about asphalt roadways, Mr. Deacon stating that he had had no experience of them; the gradients in Liverpool not allowing the use of asphalt. He had been struck with the unanimity with which every speaker on that occasion urged the necessity of a solid foundation for a good road. Asphalters were especially of that opinion. An asphalt road was in reality a concrete road with a surface of asphalt put upon it to carry out certain ends. If the concrete foundation were taken away, or tampered with, or negligently laid, asphalt itself would form a very sorry paving. In dealing with that question, one important point to be considered was the obligation under which the engineer or surveyor was placed to have the road closed for paving for the shortest possible time. For that reason his company had always urged the desirability of laying a concrete composed of a quick-setting Portland cement with the best obtainable ballast. As far as his experience went, if a lime concrete was sealed up hermetically by asphalt on the top, there was no knowing what might happen underneath; whereas, if Portland cement concrete were left open for a few days and then covered with asphalt, engineers could form a pretty good idea of what would happen. In London they were indebted to the French asphalters for all that they had first learned as to the nature and treatment of asphalt; but he thought that they had now beaten their instructors, putting down better

* *Vide* Minutes of Proceedings Inst. C. E., vol. lviii., p. 1.

work and maintaining it better. He had been struck on a recent visit to Paris, with the condition in which some of the roads had been allowed to get. He believed that it had partly arisen from the system there adopted of requiring the contractor to take up every year, whether it was required or not, one-fifteenth of the work laid down, which he regarded as a premium on bad work. Another reason was the use of lime concrete with lime mortar on the top. The only failure that he knew in Val de Travers roadways had been in connection with the use of lime concrete under lime mortar in the roadway laid (after that in Threadneedle Street) in Holborn, opposite Gray's Inn. It had been laid by Englishmen who were novices, and who followed slavishly the specification prescribed by the French engineers. That specification prescribed a layer of about 9 inches of lime concrete with $\frac{3}{4}$ inch of lime mortar. When the concrete was ready to receive the asphalt, a fire broke out in Holborn, and the barriers protecting the concrete were broken down; the place was flooded with water, the engines drove over the concrete, and the population of Gray's Inn Lane trampled it down. It was subsequently made good; the asphalt was spread, and some time afterwards the Val de Travers Company succeeded by inheritance, to its maintenance, and certainly it had been a "heritage of woe." For five or six years they had kept up the road at considerable expense and trouble, and at the end of that time they received the permission of the road authorities to relay the whole in two longitudinal strips, so as not to stop the traffic. On removing the asphalt it was found that the lime concrete had never set, that the mortar floating had never adhered to the concrete, but was mostly in powder, produced either by the action of the rammers, or by the traffic afterwards. They broke up the concrete, sifted out the lime, relaid the foundation with Portland cement, and put fresh asphalt on the top. That was done about four years ago, and the work had since proved satisfactory. Some of the workmen now in his employ, who had been previously engaged in Paris, had told him, that in several of the roads there the asphalt had been laid upon the existing macadam. The author had referred to certain roadways of asphalt with granite channels. It appeared to Mr. Harrison that granite channels were superfluous. As between an asphalt roadway with a granite channel, and a granite roadway with an asphalt channel, *qua* channel asphalt would be the preferable material. The Val de Travers Company had laid a great many footpaths in England, both in mastic and in compressed asphalt, and he was of opinion that it was not desirable to have the material of a less thickness than $\frac{3}{4}$ inch. Some years ago they laid $\frac{1}{2}$-inch mastic footpaths, but the result had not been such as to encourage that mode of construction. It had even been adopted in some of the streets in the City of London having the heaviest traffic, such as Gracechurch Street and King William Street; but in four or five years the footpaths had become so much worn that it was thought desirable to take up the $2\frac{1}{2}$ inch mastic and lay down $\frac{3}{4}$-inch compressed, which had stood fairly well. He had been surprised to hear that his company had been credited with a preference for lime concretes over cement concretes for footpaths. That was far from being the case. The footpath referred to was laid as a sample under some special conditions. It was a fact, that in certain footpaths, particularly those in the suburbs, where there was little traffic, transverse hair cracks appeared from time to time. The first cracks to which his attention had been directed, were in the footway round the garden in Leicester Square, and appeared six years ago. The cracks were there to the present time; they had not in any way affected the stability of the work, but they were unsightly, and he should be glad to be able to prevent them. He had noticed that the better the concrete on which the footpaths were laid, the greater the number of cracks appearing in them, and the worse the concrete the fewer the cracks; indeed, if they laid the concrete bad enough there were no cracks at all. He had found it impossible to lay a horizontal riband of good cement concrete 3 inches thick without finding a hair crack at every 10 or 20 feet. The crack in compressed asphalt followed the crack in the concrete. Of course the footpaths were not subject to that hardening effect which was produced by the

rolling of wheels on roadways. He never remembered seeing a crack in an asphalt roadway, although he had little doubt that cracks might be found in the concrete underneath. Mastic asphalt being more elastic than compressed asphalt, the tracks were not so numerous in it. Nevertheless he was of opinion that, *cæteris paribus*, a compressed footpath was a more desirable one than a mastic footpath. It was pleasanter to walk upon, owing to the absence of grit; it was handsomer, and it was also cheaper to lay; moreover, it had not the disagreeableness of mastic footpaths, arising from the smell of the burning asphalt in the cauldron. With regard to the surface duration, he believed that the compressed asphalt was better than the mastic. He was not surprised that very little had been said on the subject of slipperiness in connection with asphalt. The matter really lay in a nutshell. Roads when dirty were slippery, whether paved with granite or asphalt; but in the case of granite, a slipping horse might be pulled up by the joint of the second or third stone, whereas on an asphalt road there were no joints to prevent a fall. The true remedy was to keep the roads clean, as was done in Paris, where the asphalt road was a favorite one with cabmen and omnibus drivers. He was glad to find that, quite recently, the City authorities had arranged to have a certain number of hydrants used for washing the streets. He hoped that the experiment would be carried out carefully, and that the streets would be washed every morning before the traffic commenced.

Mr. H. S. Copland said that the paper, although its title was "On the use of Asphalt in Engineering," dealt only with one kind of asphalt, the Val de Travers, and of its use chiefly in the construction of roads, or rather in the coating of road surfaces, which was only a small branch of a large and important subject. He maintained that asphalt was wrongly used if employed as the surface of a roadway. Engineers had to consider other things besides the cleanliness of the material and its noiselessness. As to the latter, though asphalt was free from one class of noise, it was attended with another—the clatter of the horses' hoofs, which was very irritating to persons of nervous temperament. Nor was it enough to pay attention to the durability of the road; they had also to take into account the foot-hold given to horses, and the amount of tractive effort required, not only to draw the vehicles along the road, but to start them; and they had further to consider the cost of construction, maintenance, and cleansing. In regard to cleanliness, a good asphalt road was undoubtedly the best that could be constructed, and as to its impermeability to water, thus affording a protection to the foundation, it was also an excellent material; but for slipperiness and deficient foot-hold it was about the worst road in existence. As laid by the Val de Travers Company, it was exceedingly durable, but it was costly in the first instance as compared with other materials. Taking all the requirements into consideration, he had arrived at the conclusion that for the surface of a road no material was equal to wood. But in order to obtain a good foothold on wood, it was necessary to leave spaces between the courses, principally for the want of which the old wood-roads of twenty years ago had fallen into disuse. Other reasons for their discontinuance were that they had not been placed upon a proper foundation, and the blocks were not properly cemented or keyed together. He believed that the proper mode of using asphalt was to lay a damp-proof course of that material (to prevent the infiltration of water) on a foundation of concrete, and then to place wooden blocks upon the asphalt layer to take the surface wear of the traffic. The blocks were not only keyed to the concrete, but they were keyed to each other by the asphalt running into the joints, thus forming a monolithic slab of material, which afforded a good foothold, could be readily kept clean, and was comparatively noiseless. As such a slab extended from one side of the road to the other, the weight of the traffic was transmitted over a large area, and was not confined to one block; the road being elastic, would wear uniformly; it would not press too directly upon the concrete foundation, and particularly on one part of it, and a smaller depth of concrete would suffice. Such a surface, if the wood were properly selected, would remain perfect for a number of years. In

Boulogne, four and a half years ago, he had laid down blocks only half the depth of those used in London, for a traffic exceeding 120,000 tons per annum in a street 20 feet wide. The surface was still perfect, and there were no depressions. The wear was solely from surface attrition, and had amounted to about $\frac{3}{16}$ inch per annum. The London company formed to work his English patent had laid 60,000 square yards in London roads which had not in some cases worn quite so well as the road in Boulogne, in consequence of the wood not having been so well selected. The cost of such a road, fit for the heaviest traffic in Paris, would be from 12 to 15 francs per square meter (the amount given for the road described by the author being 17 francs), and the average cost of maintenance would not exceed 1*s.* per square meter per annum. He therefore maintained that his road, while offering all the advantages of freedom from noise, and being a better road for traction, would cost the municipality of Paris less, over a term of years, than asphalt. With regard to slipperyness, it appeared from the report presented by Mr. Haywood to the City Commissioners of Sewers in 1873, that on granite pitching one horse fell for every 132 miles traveled. On Val de Travers asphalt one horse fell for every 191 miles traveled; and on wood pavement (not asphaltic wood pavement, but the nearest approach to it), one horse fell for every 446 miles traveled. But the nature of the falls ought to be taken into consideration. Of the total number of falls on wood pavement, only one-eighth might be called dangerous, while three-sevenths of those on asphalt were dangerous. The danger was not simply from broken knees and from directly observable damage done to the horse, but from sprains in the attempt to regain a foothold. Injury of that kind was far more serious, more insidious, and less easy of cure. He concluded that, in all crowded streets, asphalt as a surface pavement should be given up. He agreed with Mr. Scott, that it might be used with advantage for the paving of narrow courts, alleys, and play-grounds for children; but the safety of grown-up people ought also to be considered, who, in crossing crowded thoroughfares, were constantly run over by horses, which on asphalt roads trotted at a great speed, and were pulled up with difficulty. The durability of all roads depended to a great extent upon the character of the concrete. He found that lias lime, properly used, was as good as cement, but it was necessary that it should be ground to a fine powder, and that it should be fresh and uniformly mixed, care being taken not to use too much water.

Mr. E. A. Cowper observed that no one had touched upon the cheap method of making footpaths in the neighborhood of London, with tar and gravel, as now practised. A few years ago the material was mixed with stones and gravel, forming a sort of pudding, the whole thickness being put in at once, and as soon as the hot weather came, the tar exuded from the top, making a very bad, soft footpath. Of late years large stones alone had been put at the bottom, which, having received a coating of tar or pitch, just touched each other at points with their tarry surfaces. Above that a thin coating of finer material was placed, with a thin coat of fine stuff on the top. This made a splendid path; no tar exuded from the top, as any surplus drained down to the bottom, and the path was firm, hard, durable and clean.

Mr. J. Lovegrove desired, having had some experience in the use of asphalt on public footways, to make a few remarks. In the year 1869, when in Paris, he observed the peculiar condition of the roadway opposite the Tuileries; the asphalt appeared to have worked up into leaf-like layers, in a plastic state, and those layers occurred at distances of about 100 feet. He had little doubt that the cause was that the road had been repaired with asphalt too rich in bitumen. In the same year he also observed the paving of the road along the Rue St. Honoré; the process appeared to be different from that which was now adopted. There was first a layer, 4 inches thick, of hydraulic lime concrete, and then a layer of about 1 inch of mortar troweled. The concrete was beaten with instruments similar to the tools used by gardeners for beating turf. On the top was a 3-inch layer of powdered asphalt; the channels were pressed into form by a rammer about 9 inches long and 2 inches thick, and were well rammed; then a heated roller was applied over the whole surface. A roller with

eight or ten carriage wheels, working upon a common axle, was also passed over it in various ways for a considerable time. Before he left Paris a considerable portion of the asphalt had to be taken up, and he believed the whole was reinstated He well remembered the care with which the concrete used in Threadneedle Street was mixed, and the quiet, steady way in which the foreigners worked upon the asphalt. It was a unique piece of work, and he would urge upon all asphalt representatives to endeavor to repeat it elsewhere. Great difficulty had been experienced in keeping in order a short piece of asphalt roadway opposite Hackney Town Hall, divided into three slips by tram lines, the tram-rail and the asphalt being too unlike to be kept together. He had recently tried a rough course of granite pitching at the side of the rails, which seemed to promise well. If well-dressed stones were laid in bond course, he thought they would answer very well. In 1872 a sample of asphalt had been laid along the footpath at Dalston Junction for a length of 550 feet, by the Val de Travers Company, and a second length was laid by the Limmer Company. The first sample near Dalston Junction, being subjected to the greater wear, was renewed eighteen months ago; the other length was now wearing near the fence line, the concrete being exposed in patches. In 1874, a layer of $\frac{3}{4}$ inch of compressed asphalt was put along the busy part of Kingsland, and a path was also laid in a quiet street in Stoke Newington. Shortly after cracks appeared at intervals of about every 12 feet, which he attributed to the contraction of the material during cooling. He did not believe that the concrete was affected. He had that day gone over a portion of the work and tested one of the cracks, and found the concrete quite sound. He had placed upon the table rubbings of three worn-out places; they looked more like a representation of the craters of the moon than a worn-out asphalt path, but it was an interesting mode of showing the condition of the footpath. Since 1876 about 160,000 superficial yards of gritted mastic asphalt had been laid in Hackney;* it was $\frac{3}{4}$ inch thick, and rested upon a bed of 3 inches of concrete. The work had been executed partly by the Limmer Company, the French Company, and Leopold Stiebel. Where the paths were narrow and the stream of traffic persistent in one track, the concrete was making its appearance in small patches. Sometimes in wide paths the stream of traffic was persistent next the fence line, and in these cases the path was apt to wear out. He would suggest that it would be advisable in such instances to lay an extra thickness. Of course, the fall would influence the traffic; if too much fall the traffic would be almost sure to keep to the fence line. It had been said that the quality of the Val de Travers asphalt was proved by its wearing to a film, but that was not peculiar to that asphalt, as the Limmer Company's asphalt behaved in precisely the same way. Common asphalt was more easily fractured, and would not wear to a fine film.

Mr. Alfred Davis observed that the compressed asphalt blocks used in Paris were stated to have been unsuccessful. In the United States a block was made of refined and tempered Trinidad asphalt and finely crushed limestone, thoroughly heated and mixed in about equal proportions, and afterwards subjected to a uniform pressure of 1 ton to the square inch, or about 50 tons to the block. The standard size was 12 inches long, by 4 inches wide, by 5 inches deep. The blocks had been laid in several of the New England States, and he believed were being extensively used in New York, Philadelphia, and other American cities. He had seen a piece of this roadway in Philadelphia, after six years' wear, and it appeared in first rate condition, although the blocks were inferior to those now produced. In laying the compressed asphalt block road, a concrete foundation at least 4 inches thick was provided, over which a thin coating of gravel was spread; upon this bed the blocks were set close together and heavily rammed. The great advantage of this roadway was that it afforded a good foothold for horses, and at the same time possessed all the other advantages of asphalt roads as constructed in this country. The press employed in the manufacture of these blocks had a steam cylinder of 40 inches in diameter, worked with a pressure of 90 lbs. per square inch.

* *Vide* Annual Reports to the Board of Works for the Hackney district.

There was an ingenious automatic arrangement for forcing the block out of the mould, and carrying it away to any desired spot for storage.

Mr. FREDERICK COX, Chairman of the Streets Committee of the City of London, said he had no connection with asphalt companies or wood paving companies; he was not an engineer, and he had no scientific knowledge whatever, but perhaps he might be permitted to make a few remarks as to the use of asphalt, past, present and future, in the City of London. The administrators of the City Commissioners of Sewers gave encouragement to every projector to send in any kind of asphalt or wood pavement that was likely to be permanently useful. About thirty different kinds had received a fair and proper trial; most of them crumbled into dust or proved to be utterly worthless, but there were a few that had stood a severe test. In his opinion the Val de Travers was the favorite company; but other companies had laid down asphalt with good results. Mr. Haywood, the engineer of the Commissioners, who probably had had more experience in roadways than any other person in the kingdom, reported, five years ago, that, after trying the various kinds submitted, he found that good compressed asphalt was the cheapest, dryest, cleanest, and most agreeable for the general purposes of traffic, and Mr. Cox ventured to say that if Mr. Haywood were giving his opinion now, it would be expressed in still stronger language. The Commissioners had carried out large paving works both with asphalt and wood, and probably the main reason that guided them in putting down so much wood was that the asphalt, especially when put down in great lengths, was found to be extremely slippery. In very dry or very wet weather the foothold of the horses was good, but when the pavement was muddy it was extremely inconvenient. It had been suggested that all that was necessary was to clean the streets, but what could be done with a place like Cheapside, when ten or twelve thousand vehicles passed over it every day? After eight o'clock in the morning it was useless to attempt to do anything of the kind. At six o'clock that very morning Cheapside had been thoroughly cleansed; at nine o'clock it had not dried, and it was in that peculiar state that, although quite clean, it was very slippery. Grit had to be thrown upon it in order to enable the horses to stand, and that state of things continued until the afternoon, when the rain came on and converted the grit into mud, which was probably so still, unless the heavy rain that had since fallen had washed it into the gullies. If cleanliness could be accomplished, in his opinion asphalt would be the best roadway for all the main streets; its use had, however, been attended with great difficulties, and the authorities had not yet decided which plan to adopt. To show the difficulties that were experienced, he might mention that three years ago the Commissioners commenced washing the streets, but they were threatened with an injunction from the Court of Chancery for washing concrete down the sewers. The Metropolitan Board of Works, who had the care of the main sewers, said, "It is all very well to wash your grit into our main sewers, but we must be careful what we do, because the Conservancy Board are threatening an injunction against us for raising shoals in the bed of the river." That, however, did not frighten the authorities in the City, who went to an expense of £10,000 in providing large catch-pits to the gullies in the City in order that the deposits might be removed, which was done almost daily. Then arose a question about the water carts, which caused so much obstruction in the crowded streets that the police interfered. The authorities had endeavored to deal with that, and they had spent £20,000 during the last two years in erecting hydrants in every street and court in the City, both for the purpose of extinguishing fire and of watering the streets. Those hydrants were just completed, but had not been set to work. With regard to wood pavement, he believed it was one of the dirtiest and greasiest pavements ever put down in the City of London. Dirt was carried from it over 100 or 200 yards of the asphalt, and rendered that which was previously clean excessively dirty. He believed if the Commissioners could succeed in getting clean asphalt, so as to avoid slipperiness, wood pavement would make very little progress in the City of London, exept up gradients that were not suitable for asphalt.

Mr. W. H. Delano, in reply, said his experience in reference to scavenging was confined to Paris, where the work was effectually done both in wet and dry weather. Gangers were constantly at work, and they were paid about 3½d an hour. The gully holes placed under the curbs were large and the drains were roomy, so that the slush was easily passed down them. Hydrants had been erected all over the city, and after heavy rains they were used to flush the roadways and carry the mud into the drains. Of course it got into the river and formed banks, but that was the affair of other authorities. He would suggest that the catchpits to which Mr. Cox had alluded might be emptied by a pneumatic system of pumping into carts. Formerly mud carts were employed with revolving brushes to take up the slush; but he believed they had been superseded. It was evident that scavenging could not be done in London without considerable expense; but probably London mud, like Paris mud, contained fertilizing qualities, so that some set-off might be obtained. With regard to the granite sets in Paris to which Mr. Ellice-Clark had referred, he had given particulars of the cost, and also of the cost and maintenance of the macadam, in the appendix to his paper, and an interesting report had been presented upon the subject by M. Vauthier. As to the cracks which had been so frequently mentioned, he believed they resulted in nine cases out of ten from the concrete. If mastic asphalt was placed on wet concrete it would blister and sometimes crack, especially if the bitumen used as a flux to melt it was not well purified. Some engineers used straight joints to prevent cracks. He had also seen hoop iron put in between the concrete at certain distances when it was not too thick. It was always well that the asphalt, liquid and mastic as well as compressed, should be sufficiently thick. Unfortunately Municipal Boards often required things to be done cheaply, and hence the thickness of the asphalt was less than it ought to be. In Paris, where a fifteenth part had to be renewed every year, thickness was not such a desideratum. In the case of gritted mastic, the thinner the mastic the finer the grit should be. Where the mastic was thick, a coarse grit might be used, as shown by the specimen of asphaltic concrete on the table. There were few compressed footpaths in Paris. In 1874 he laid on the Pont Royal about 200 square meters of this material, under the orders of M. Allard, now Chief Engineer of the City of Paris, and it was now in good order. At one part it was laid $\frac{9}{16}$ inch thick, in other parts $\frac{3}{4}$ inch, and in others 1 inch. It had a better appearance than mastic, but it cost more, because the thickness was greater. The specific gravity of compressed and mastic asphalt was about the same, but the grit put into the mastic made it harder than the compressed material. The statement that asphalt neither contracted nor expanded was certainly an error. Of course the laying down of footpaths with gritted mastic depended a great deal upon the climate. In Marseilles the workmen would put into the cauldrons as much grit as they did asphalt, making a stiff mixture, which required great muscular strength to lay down $\frac{9}{16}$ inch in thickness, but when it was laid it answered very well. No practical worker of asphalt would ever use compressed asphalt as a coating for masonry, because it had not sufficient elasticity. Coatings of masonry were generally put down $\frac{9}{16}$ inch thick, and they required a good deal of bitumen; sometimes the layers were vertical, at other times convex, and frequently had to be inserted in recesses in the mansonry prepared for the purpose. Portland slabs had been suggested as a concrete, but he did not think they would answer, because they would require concrete underneath to keep them level. He had been reproached for not having alluded to asphalt as a covering for roofs, but his experience having been limited to France, where such applications were well known, particularly in the south, he supposed that engineers in London who were familiar with such applications would themselves refer to them. The applications of asphalt were almost endless. He had just seen a veteran asphalter in London who had shown him some work that he had done at the Horse Guards stables forty years ago. Up to the 31st of December, 1877, the chief cause of the want of stability of the compressed asphalt roadways in Paris was owing to the hydraulic lime concrete being only 4 inches thick, covered with a

lime mortar floating, whereas a layer of 6 to 9 inches of Portland cement without floating was indispensable. Since the 1st of January, 1878, Lobsann asphalt had been used instead of Val de Travers and Seyssel, as heretofore, which, according to the report of the Paris engineers, had not sufficient stability. Seyssel mastic was chiefly employed in France for footpaths and coatings for masonry, whereas Val de Travers had been more largely used for compressed asphalt roadways, although by no means exclusively. Wood pavement had not succeeded in Paris, the only important specimen on the patent plank foundation being the Rue St. George's, which was partially in a bad state, although subject only to light traffic. In several cases wood pavements had been taken up in Paris within the last eight years, and replaced with granite sets and compressed asphalt. Wood was not a material of invariable density like compressed asphalt, the heart being always harder and less absorbent than the outer rings. It had, however, the great advantage of comparative insonority, though vibration was perceptible, and it was excellent for inclines exceeding 1 in 50. He thought that sound oaken sets, with beveled edges carefully laid on good cement concrete, with ¼ inch joints filled in with pure asphalt mastic, would render good service for roadways in dry climates, but he doubted if any pure wood pavements would last in Paris or in London much over three years without costly repairs. The smell from rotting wood pavements saturated with the filth of large towns must be deleterious. It was well known in Paris that Sicilian asphalt had been taken out of the list of asphalts approved by the city engineers for roadways since 1872. He had been prohibited from employing about 1,500 tons from Ragusa, Sicily, for roads in Paris, and had used a good deal of it as ashlar. This rock was available for flags, staircases and balconies; it was susceptible of delicate carving for architectural ornaments. There were three qualities, one rich in bitumen, the second medium, and the third poor, the latter being a coarse-grained yellow stone with the appearance of sandstone. If it would last three years under heavy traffic in London without repairs, such a test would class it as a material for roadways. It was quite possible to make bad work with good materials, though the converse was not true. Still, when good asphalt, properly ground and heated and well laid by careful workmen, did not stand, it was almost always the fault of the concrete. Laying on wet concrete, or using burnt powder was sometimes a cause of failure. Sets of pure Seyssel and Val de Travers powder, compressed in a mould 4 inches square and 2 inches deep, had been successfully used in Paris, but there would be a difficulty in repairs; it was also cheaper to lay hot powder in large towns. Some artificial sets, 8 inches cube, composed, he believed, of gas tar mastic and gravel, had been laid last autumn in the Rue Neuve des Petits-Champs, at the angle of the Rue Vivienne. The piece had been frequently repaired, as the surface wore away and crumbled under the traffic, which was not heavy. He had no confidence in bituminous concrete for roadways, except when used as a foundation for compressed asphalt, instead of Portland cement concrete. With reference to the Seyssel and Val de Travers mines, he had hoped that the engineers who had worked them would have been present and given personal explanations. He might mention that the mines were easily worked; there was no chokedamp in them, and little water. The rock was blasted with powder, dynamite not being used because the asphalt was tenacious in its nature. It had been stated that the test of asphalt was its durability. His object in writing the paper was that any engineer, surveyor, or architect, in specifying asphalt might have some other test. Asphalt might be adulterated; but the tests he had given would enable an architect or engineer to satisfy himself. With reference to the question of nomenclature, "asphalt concrete" had been alluded to in Mr. Deacon's paper; but he was sure from the context that gas-tar concrete was meant, which was a different thing. Mr. Cowper also had referred to pitch and tar pavements; but pitch and tar were not asphalt. It was most important not to confound them in specifications, as their respective values and properties were widely different. Considerable areas of compressed asphalt

had been laid in Berlin, Vienna, Pesth, Brussels, and New York, and he regretted that no engineer had described the mode of laying.

CORRESPONDENCE.

Mr. MAURICE BIXIO, President of the Paris General Cab Company, owning about twelve thousand horses and six thousand vehicles, gave the results of his experience as to the most suitable material for roadways for vehicular traffic. The worst pavement was porphyry (grey Belgian granite sets, 4 inches by six inches). Falls of horses were much less frequent on asphalt, macadam, or rough pitching (sets of Fontainebleau gritstone 8 inches cube). For the horses, falls on asphalt were less dangerous than on any other material. Beyond all doubt traction was less on asphalt than on any other pavement. His company had made many experiments on this subject, from which he would quote, at random, the following, relating to the French four-wheeled cab, weighing 658 kilogrammes (1,447 lbs.):

	Kilogrammes.	
Traction on rough pitching.....	16.37	(36 lbs.)
Traction on small sets.....	14.79	(32.5 lbs.)
	Min. Max.	
Traction on macadam.....	14.0 to 20.5	(30.8 to 45 lbs.)
Traction on compressed asphalt (Val de Travers)	12.79	(28 lbs.)

It was probable, though difficult to establish otherwise than by comparison, that the wear and tear of the different parts of a vehicle was less rapid on asphalt than on other pavements. But the comparison did not apply in its entirety to macadam, in which case the tires of the wheel and the horse shoes were the only parts that wore out more rapidly than on asphalt. The difference of wear was due to the jolting produced by sets, which naturally induced friction between all parts susceptible to that action. He thought that traction being less, fatigue to the horse would also be less; but that was only an opinion, and not based on actual experiment. Asphalt was excellent also for granaries and for lining wooden mangers. For the paving of stables his company had made few experiments with the material, but as far as they had gone they were well satisfied.

Mr. ERNEST CHABRIER wished to deprecate a practice which had been tolerated for some time in the depots of the City of Paris, viz., the mixture of several kinds of asphalt, with a view to obtain an average quality which would be supposed capable of meeting general requirements. The principal quality to be sought for in rock asphalt for laying on roads was, the greatest possible homogeneity in the grain of the limestone, and equal regularity in the amount of the bituminous matrix. The greater this uniformity the longer would be the endurance of the asphalt roadway. He would illustrate this by referring to the fact, well known by all engineers concerned with roadmaking, that a mixture of hard with soft metal formed a less enduring surface than one of the softer material alone. The uniform wear of all parts maintained cohesion, which, on the contrary, was rapidly destroyed when a piece of hard stone was, from continual vibration, displaced, without being crushed, thereby leaving a hole. When asphalt rock was not suitable for road surfaces it was either too poor or too rich. In the first case the particles did not cohere; in the second the carriage wheels sunk into the material. The practice had been allowed of mixing these two kinds of rock in proportions impossible to be accurately determined, the process being left to the rule of thumb of the workmen. It was only reasonable to suppose that the requisite care was not always bestowed, and in case of bad mixing bad work would result, and a much more rapid deterioration must be expected, on account of the non-homogeneity of the material. It was, therefore, most important that persons proposing to lay down asphalt roadways should, above all things, get the particular rock best suited for the purpose, and further, should seek to obtain it of as even texture as possible.

Mr. LAVALLARD, Director of the Stock and Forage Department of the Paris General Omnibus Company, gave some information relative to the traction of heavy vehicles on asphalt carriageways. The standard omnibus of the Paris Company weighed from 1.67 to 1.77 ton empty, and from 3 to 3.6 tons when full. The diameter of the fore-wheels was 4½ feet,

of the hind-wheels 5 feet, the width of the tires being 2¼ inches. The new three-horse omnibus weighed, when full, from 5 to 5½ tons; the diameter of the fore-wheels was 3¾ feet, and of the hind wheels 5 feet, the width of tires being 3⅛ to 3½ inches. The company's tramway omnibus* weighed, when full, 6 tons, and the diameter of the wheels was 3½ feet throughout. The result of daily experience showed that when the weather was not very warm and the asphalt remained hard, traction on this material was less than on ordinary roadways; but that when the asphalt became softened, by the heat of a fierce sun, traction became considerable and augmented with the rise of the thermometer and the weight of the vehicle. When the asphalt was either dry or wet it afforded a good foothold for the horses. But when the asphalt was beginning to get wet or beginning to dry the horses had much difficulty in keeping up. Under such conditions the asphalt was slippery, and the fall of the horses became frequent. This did not, however, affect the traction of the vehicles, which still remained less than on other roadways. The wear and tear of tires, axles, harness, &c., was less on asphalt because shocks were imperceptible. Although, under the conditions named, horses fell more frequently on asphalt than on granite sets, the injuries received were less serious. It, however, resolved itself into a question of shoes, and he thought the adoption of the Charlier horse shoe had met the difficulty. His company had found that asphalt succeeded perfectly as a flooring for granaries and forage stores, but not so well for stables, where it had in most cases to be abandoned, owing to the weight of the horses (from 10 to 12 cwt. each) causing depressions in the material when softened by the warmth of the recumbent animal. The urine collected in these holes, and, moreover, the asphalt was too smooth for the straw, which was always found kicked out behind the stall. Perhaps for horses of a lighter build the inconvenience would not be so great. Latterly they had had reason to believe that the consistence of the subsoil had some influence on the question, because they had stables wherein asphalt floors laid ten or twelve years ago were still in good condition. The cost of maintaining the asphalt laid along their tramways was 1 franc 20 centimes per square metre per annum.

PROPOSED SYSTEM OF INCLINED PLANES FOR MOUNTAIN ROADS.

By ED. M. ROGERS.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

AT present the railroad system of the world has reached an extent of 123,000 miles, involving in its construction an expense of $11,255,000 and the consumption of more than one-half the total iron production. This excessive cost is due, in a great measure, to the necessity of using comparatively light grades rather than making the roads conform to the surface of the ground.

With a view of obviating this difficulty many ingenious systems of gravity railroads have been proposed, with varying success, but they are all open to serious objections which have heretofore prevented their general introduction. With very few exceptions the overcoming of steep gradients is confined to the friction of smooth drivers on smooth rails.

At a very early date in the history of railroads, the discovery of coal in the Lackawanna Valley directed the attention of engineers to the problem of its transportation, across the mountains, to a seaboard market. The result of their investigations was the construction of the noted gravity system of the Delaware & Hudson Canal Co. This system involves two independent sets of inclined planes, each set being arranged in the order of a short, but steep plane, followed by a

* The vehicle used on the tramways of the Paris Omnibus Company is not a car as usually understood, but merely a big omnibus on flanged wheels. The tramway companies use cars of the same character as those in London.

long one, the inclination of which is reversed and is only sufficient to overcome the friction of the cars. At the summit of these planes are situated stationary engines, provided with suitable drums and endless wire ropes. Arriving at the foot of a steep incline, the trains are attached to the rope and elevated to the summit by the action of the engines, being then in position to descend the long inclines in virtue of their potential energy.

The second set, which is in some places several miles distant from the first, has its planes reversed and is intended for the return of the empty cars.

This is, doubtless, the cheapest method of transportation, through mountainous districts, provided there is traffic enough over the line to keep the stationary engines in constant use; for what would represent the friction of a train for a long distance on a supporting grade is concentrated in overcoming the gravity of a short plane.

Yet, notwithstanding the utility of this method, in special, and the entire railroad system, in general, there is still a want felt which calls for, and has, in some measure, received the attention of engineers of to-day. I speak of lateral roads through mountainous districts intended as feeders of main trunk lines, over which the traffic is not sufficient to warrant the expense attending the construction of long lines, with light grades, or the operation of gravity roads with stationary engines and rope haulage.

Since it is the purpose of this paper to propose and discuss a system of planes for lateral roads, perhaps it will be well to mention some of the kindred devices already in operation, in order to bring them into comparison with the proposed plan.

In June, 1876, an article appeared in this MAGAZINE by Mr. Henry Handyside, stating the problem of inclined roads, and proposing to solve it in the following manner:

The greater portion of the line was to be constructed with such a grade that the ordinary locomotive might be able to draw over it trains sufficiently large to accommodate the traffic of the region through which it passed. But, in order to overcome the required elevation, occasional planes, not exceeding one in six, were to be thrown in at such places as the character of the country might warrant. A plane of one in six is the maximum inclination over which a locomotive can proceed, without a load, and in all kinds of weather. Since, then, none of the planes were to exceed this limit, the locomotives could always climb them, and it only remained to provide suitable means of elevating the trains. To accomplish this, each locomotive was to be provided with winding gear and steel wire rope, driven by auxiliary engines. In addition to this they were to carry powerful gripping struts which, by their action on the rails, might be capable of holding the entire train. Arriving at the foot of a plane the engine was to be uncoupled and proceed up the hill, at the same time playing out the wire rope from its winding drum. At the summit it was to be anchored by means of the gripping struts, thus virtually changing the entire machine into a stationary winding engine, by the action of which the train might be elevated.

This method was practically tested in England, and met with some success, though its introduction was very limited, and, I believe, it has since been abandoned.

Another method which has received some attention, but which has not, as yet, been practically tested, is briefly as follows:

The grade of the road is arranged like that of Mr. Handyside; that is to say, there are no inclines so steep but that a locomotive, detached from its train, can climb them. The method of operation is also similar to that above described, the only essential difference being in the manner of changing the locomotive into a winding engine. In this case, upon arriving at the summit of a plane the locomotive is anchored over a pair of friction drums on which the drivers act, causing them to rotate and put in motion a set of winding gear, by the action of which the train is elevated.

The main advantage which this system offers over that of Mr. Handyside is, perhaps, the difference in expense between the equipment of the planes with suitable drums and gear in the one case, and providing each locomotive with the necessary appliances, in the other case. This would, of course, vary

under different circumstances, and perhaps there can be no general comparison between the two.

The toothed-rail system used on the Mt. Washington and the Rigi Railways is so familiar that mere mention of those celebrated roads will stand in lieu of a full description. The name "third grip rail" used on the Mt. Cenis Railroad, explains itself.

Many other ingenious methods of overcoming elevation have been proposed, but explanations of them, although perhaps interesting, would not be compatible with the limits of this paper. Let us, therefore, proceed to explain the device proposed in this paper.

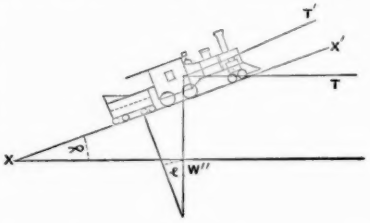
In order to make plain the problem under consideration, it may be repeated in a more specific form. Let us suppose that a trunk line wishes to extend a branch into some mining district where the elevation to be overcome is great, but the character of the country such that most of it may be mastered in one or two short inclines, if safe and economical means of climbing them can be devised.

In overcoming ordinary grades, and in all attempts to climb steep gradients, the real process is a change of kinetic energy, or energy of motion into potential energy, or energy of position. In all locomotive systems now in operation, no attempt is made to utilize this potential energy after it has been attained. On the contrary, outside of the mere descent, it is a troublesome element which has to be overcome by brakes. If it can be put to practical use its superiority over kinetic energy, which must be generated for the occasion, is manifest.

Let us suppose that we have a train of loaded cars, whose weight is P, at the summit of a steep incline, and let it be connected with a counter weight, enough lighter than itself to provide for friction. The train descends and the counter weight ascends, and is then in position to eert its potential energy in elevating another train, provided it is lighter than the first. When the traffic down the plane is greater than in the opposite direction, the system may be operated without the aid of an outside motor. It is, indeed, a method very often used in mining operations where ore or coal is to be transported from a higher to a lower level.

If to the train at the summit of the incline a locomotive is attached whose weight is W, and if, for the moment, friction is neglected, it is evident that the entire train will be capable of elevating a counter weight weighing $P+W+W'$, W' being an additional weight, due to the traction of the locomotive, and depending upon the inclination of the plane. The counter weight will, in turn, be capable of elevating a dead weight $P+W+W'$ or a train weighing $P+W+2W'$ provided it is also drawn by a locomotive. By properly choosing the inclination of plane and weight of counter weight, the system will be under the full control of the locomotive, and entirely independent of the preponderence of the traffic down the plane. But before discussing this case let us determine the value of W'.

The adhesive power of a locomotive is evidently the limit of its tractive power, and may be substituted for it in determining the maximum load. It varies greatly according to the condition of the track, but may be safely taken at one-fifth the insistent weight on drivers multiplied by the cos. angle of inclination.



Let us now investigate the load which a locomotive will draw on a level, and then extend the investigation to inclines suitable for systems intended to overcome great elevation.

Let W'' = total weight of train.
" T = traction of locomotive, on level.
" a = angle of inclination.
" f = coefficient of friction, of train.
" T' = traction of locomotive on plane.

Projecting all the forces upon the axis

XX′, the general equation of motion will be

$$(1)\quad \Sigma X=\theta(W''\sin\alpha+W''f\cos\alpha) -T\cos\alpha=o$$

θ being a variable whose value determines the direction of the motion. That is to say,

When $\theta=1$ there is equilibrium.
" $\theta>1$ there is motion up the plane.
" $\theta<1$ there is motion down the plane.

If G=weight of locomotive and tender, ρ= percentage which rests on drivers, and we take friction at 8 lbs. per gross ton, T′=T cos α and eq. (1) becomes

$$W''\sin\alpha+W''\frac{8}{2240}\cos=\tfrac{1}{5}\rho\,G\cos\alpha$$

$$\text{or}\quad W''\tan\alpha+\frac{8W''}{2240}=\frac{\rho G}{5}\quad .\ .\ .\ (2)$$

When $\alpha=o$ and $\rho=.6$ (which will be the case if the locomotive has four driving wheels) tan $\alpha=o$. Then (from eq. 2)

$$W''=33.6\ G.$$

That is, under the assumed data, the locomotive will pull 33.6 + its own weight on a level. This is a superior limit since $\theta>1$.

The load which the locomotive will pull on any grade may be found by substituting the proper value for tan α in (eq. 2), and to find the maximum grade over which the locomotive will travel when detached from its train, it is only necessary to substitute W″=G in the same equation

$$G\tan\alpha+\frac{G}{280}=\frac{.6G}{5}$$

whence, tan α=.11642 which corresponds to a grade of 1 in 8.5.

If the locomotive is so constructed that the entire weight is thrown upon the drivers, $\rho=1$ and the grade may be increased to 1 in 5.

Assuming the inclination to be one in nine, and supposing the locomotive to be at the summit, it will (according to what precedes) elevate a counter weight, the weight of which may be determined from the formula

$$Y=G+W''-2F-F'\quad .\ .\ .\ (3)$$

In which

Y = weight of counter weight.
G = " " locomotive and tender.
F = friction " " " "
F′= " " sheave journals, ropes, etc.
W″= total load which locomotive will draw upon the incline.

W″ may be determined from eq. (2) by making tan $\alpha=\frac{1}{5}$

$$\tfrac{1}{5}W''+\frac{W''}{280}=\frac{.6}{5}\ G$$

$$\text{or}\quad W''=1.05\ G.$$

Since we have assumed 8 lbs. per gross ton to be the amount absorbed by friction of train,

$$F=\frac{8G}{2240}\quad 2F=.007\ G.$$

In determining the last member (F′) it is only necessary to obtain the initial friction, or that which must be overcome in order to set the system in motion. Since the pressure on journals is 2 sin α =.14 Y, and the coefficient of axle friction for wrought iron on brass is .075, the initial friction will be .14 Y × .075= .105 Y. Now suppose diameter of sheave=10 diameter journals, then the force at circumference of sheave necessary to overcome friction of journals =.1 ×.105 Y=.0105 Y.

Substituting these values of F, F′, and W″ in eq. (3)

$$Y=G+1.05\ G-.007\ G-.0105\ Y$$

$$\text{or}\quad Y=2.02\ G.$$

This calculation does not take into consideration either the weight or rigidity of the rope, but is sufficiently accurate to show that the system will be under full control of the locomotive, provided the inclination does not exceed one in nine, and the counterweight is no heavier than 2 G, for it can always proceed up the plane and manage the counterweight unassisted. Bearing this in mind, the reasons for the following plan for a lateral road will be manifest:

Let the mean portion of the line be built on an ordinary supporting grade, but at such places as the character of the country may warrant, let occasional planes, not exceeding one in nine, be thrown in, and let each of these be provided with suitable counterweights, weighing no more than 2 G. Then all trains

weighing less than 3 G may proceed over the planes without delay, but should they exceed this limit it will be necessary to divide them, and make two trips over the plane. If, however, the traffic can be arranged so that the counterweight will always be in position for the next train, that is, if the trains alternate in direction, it may be made much heavier and the angle of inclination may also be increased.

To illustrate this let us take an extreme case. For instance, take $\alpha=45°$ then tan $\alpha=1$, and from eq (2) we obtain the value of $W''=.12$ G, which may be interpreted thus: On a plane whose inclination is 45°, a counterweight weighing .88 G will be required to elevate a locomotive weighing G, provided the full traction of the engine is utilized. As soon as the inclination has passed the limit one in nine, the system is no longer under control of the locomotive, and there is no further necessity of limiting the weight of counterweight. But (in the case $\alpha=45°$) the trains passing down the plane must weigh at least $Y-.12$ G, and those passing up the plane will be limited to $Y+.12$ G.

In most cases these conditions would be found inconvenient if not impossible, and the use of inclinations greater than the angle of adhesion would be expedient only under very exceptional circumstances.

The construction and equipment of planes suitable for this system would be, in most cases, neither difficult nor expensive. Perhaps it will be well in this connection to give a few details. However, before doing so it will be necessary to assume data for a particular case.

Since the value of ρ exerts so great an influence upon the maximum grade which may be given to the plane, it is very essential to use a locomotive, the weight of which is well concentrated upon the drivers. This effect is best produced in what is known as a "tank engine;" and in the following details it will be assumed that such an engine is used.

Now, since the track is exposed to all kinds of weather, a poor, though not absolutely the worst condition, of the rails must be taken to compute the inclination of the plane. For frost, the adhesive power is $\frac{1}{6}$ G cos α, while for thoroughly wet rails it is $\frac{1}{4}$ G cos α and for dry rails it rises as high as $\frac{1}{3}$ G cos α. To obtain the maximum utility it would, of course, be inexpedient to assume a factor of adhesion providing for snow, for since the planes are short it would, doubtless, be more economical to clear the rails than submit the system to such unfavorable and extreme conditions. In the previous discussion the factor $\frac{1}{6}$ was used, and the value of ρ was taken at .6, thus providing for frosty rails and a tank locomotive. Under these suppositions, the inclination was found to be about one in nine. This is a somewhat smaller inclination than that assumed by Mr. Handyside and others, which is probably due to the fact that it was derived under the assumption that the rails are in poor condition.

In order to illustrate the problem let it be proposed to overcome an elevation of 200 feet, and assume available ground for a straight incline which will be 1800 feet long, since the inclination is one in nine.

From what has proceeded it will appear that when the rails are covered with frost the weight of the counterweight is limited to 2 G, or in this case, 80 tons. If, however, the rails are thoroughly wet this weight may be increased to 120 tons, and for dry track, to 125 tons. To provide for this difference and always obtain the maximum effect of the system, it is only necessary to divide the counterweight into sections weighing respectively 80, 40 and 5 tons. In good weather the total weight may be elevated by the locomotive, but when the rails become slippery the sections must be uncoupled, and the 80-ton weight alone used. A good form of counterweight, and one which would combine economy in first cost, compactness, and durability, would be simply pig iron cylinders, roughly cast around axles and fitted with ordinary car wheels. These cylinders might be connected together in groups of two, by means of side beams carrying suitable boxes for the axle journals, and the groups, in turn, coupled into a train of the requisite weight.

In cases where the proper excavations could be cheaply made, counterweight might be made less with a somewhat narrower tread than the cars, and run on a track in a covered trench, underneath the main track, thus reducing, in a great

measure, liability to accident, and securing the counterweight against all obstructions.

COMPARISON.

In the absence of accurate data it would be a difficult matter to make a close comparison between the cost of a road built on this plan, and one in which the same elevation is overcome by an ordinary supporting grade; but the following is a rough approximation to the comparative merits of one plane of the gravity system, and a corresponding portion of the common road.

As before, let it be required to overcome an elevation of 200 feet, and assume available ground for incline of one in nine, and also for the development of a supporting grade. The length of the former will be 1800 feet, while that of the latter will depend upon the grade assumed. As a gravity system would be adopted only in mountainous districts, curvature would exert considerable resistance, and should be taken into account. This is easily done, in case of the plane, by assuming the weight of counterweight to be enough greater than that of the maximum train, to overcome all resistances. Five tons difference, which has been assumed in the following discussion, is not only sufficient to do this, but would also render some assistance to the locomotive. In the case of the supporting grade, however, these resistances must be overcome by the locomotive and must be considered.

There is a custom of equating or compensating for curvature on supporting grades, by deducting from the rate of inclination an amount equal to from $\frac{5}{100}$ to $\frac{8}{100}$ of one per cent. of the distance for each degree of curvature. Thus, if we assume a nominal grade of 100 feet per mile (1.9 feet in 100 feet, or a 1.9 per cent. grade) it must be flattened $\frac{5}{100}$ to $\frac{8}{100}$ (an average of .06) feet in every 100 feet for each degree of curve, or $.06 \times 52.8 = 3.168$ feet per mile, for each degree in 100 feet. Now, let us assume something like the ordinary characteristic of alignment in a mountainous country, say a total deflection of 180° in each mile of distance or 3.03° in each 100 feet. This will call for a reduction of $3.03 \times 3.168 = 9.6$ feet per mile.

The absolute grade is then $100 - 9.6 = 90.4$ feet per mile, and the distance required to overcome 200 feet elevation is $\frac{200}{90.4} = 2.2$ miles. This means that overcoming an elevation of 200 feet and a total curvature of 180° per mile is equivalent to overcoming $100 \times 2.2 = 220$ feet on a straight track. We may therefore consider our grade as 100 feet, and distance as 2.2 miles, and pay no further attention to curvature. In this case the length of the supporting grade is

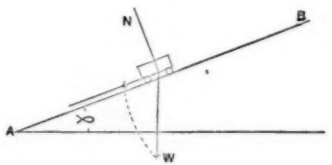
$$\frac{2.2 \times 5280}{1800} = 6.45$$ times as long as the equivalent gravity plane.

This will enable us to roughly approximate to the relative cost of the two systems, but in order to make a fair comparison of their merits, we must also take into consideration the amount of work which can be done on each in the same time.

To arrive at this result, let us first determine the time required to take the maximum train over the plane, and also the time in which the same locomotive, drawing the same load, can climb the grade.

Let H = the absolute horse power which the locomotive is capable of imparting on a level road. (If the cylinder power is large enough, H is dependent upon the adhesive power, which varies as the cosine of the angle of inclination. On an incline, therefore, the power = H cos a)

Let a = inclination of plane.
" s = length of plane, in feet.
" t = time required to pass over the distance s.
" 8lbs. = friction per gross ton, on level track.
" W = load, including locomotive, in tons.



We may derive a general expression for t from the following consideration:

Resolving W in the direction AB and taking friction $= \frac{8}{2240} N = \frac{W \cos a}{280}$ we

have for the force which the locomotive must overcome

$$W \sin a + \frac{W \cos a}{280}.$$

Now since work is pressure into distance, the work absorbed in taking the load up the plane is,

$$s\left(W \sin a + \frac{W \cos a}{280}\right)$$

foot tons, or if the ascent requires t minutes.

$$\frac{s\left(W \sin a + \frac{W \cos a}{280}\right)}{t}$$

foot tons per minute.

Since one horse power = 33000 foot pounds $= \frac{33000}{2240}$ foot tons, per minute, it requires

$$\frac{2240 s\left(W \sin a + \frac{W \cos a}{280}\right)}{33000 t}$$

horse power to draw the load up the plane. But the actual horse power expended by the locomotive is H cos a. Consequently

$$\frac{2240 s\left(W \sin a + \frac{W \cos a}{280}\right)}{33000 t} = H \cos a$$

or

$$t = \frac{2240 s\left(W \sin a + \frac{W \cos a}{280}\right)}{33000 H \cos a} = \frac{2240 s\left(W \tan a + \frac{W}{280}\right)}{33000 H}$$

If H is constant we may substitute

$$A = \frac{2240}{33000 H}$$

whence

$$t = A\left(W \tan a + \frac{W}{280}\right) \qquad (a)$$

In this formula no account is taken of the pressure of the air; but, since the velocity on the grade must be greater than that on the plane, this omission will favor the supporting grade. If the same condition of track is assumed in both cases, it makes no difference whether it be wet or dry, for the power of the locomotive will be equally limited by slippery rails. Let us then assume that the entire counterweight (125 tons) is used, and that the maximum train weighs 120 tons, exclusive of locomotive. The extra five tons of the counterweight, will easily overcome the friction of the system and keep the train pressing against the locomotive. Therefore, in the case of the plane, it is only necessary to find the time in which the locomotive, uncoupled from its load, will ascend the plane. This may be found in terms of H, by substituting in eq (a), W = 40 tons S = 1800 ft. and tan $a = \frac{1}{9}$.

Making these substitutions and reducing we find t = 8257 A.

In the case of the supporting grade, however, the locomotive must elevate, not only itself, but also the train (120 tons), making a total load of 160 tons. Therefore,

$$W = 160 \text{ tons} - \tan a = \frac{1.9}{100},$$

and $s = 2.2 \times 5280$.

From these values we obtain $t_1 = 41957$ A.

Hence

$$\frac{t_1}{t} = \frac{41957 A}{8257 A} = 5.08 \text{ or } t_1 = 5.08\, t$$

That is—the time required to ascend the grade is 5.08 times as much as that required to ascend the plane. Now let us suppose that the descent of the plane occupies just as much time as the ascent, and that 2.08 t is consumed in delays at the top and bottom. The train can proceed up the plane, the locomotive descend, elevating the counterweight, and re-ascend with another train, in the time that it would require for one train to pass over the grade.

Thus, at least twice as much weight can be transported over the gravity plane, in the same time, as over the supporting grade.

Let us now assume an average cost of construction, exclusive of equipment, in a mountainous country, say $30,000 per mile, and endeavor to arrive at the relative expense of the two systems. At this rate the cost of the supporting grade would be $66,000. If we assume that the cost of grading and tracking the gravity plane to be one and a-half times as much as the same length of main line, we will have 1,800 feet of inclined plane to construct at a cost of $45,000

per mile. The following is a rough estimate of the cost of a gravity plane. As it is made for comparison with the cost of an equivalent supporting grade, the items are assumed very high in order to be sure of covering the expense.

1,800 feet of track @ $45,000 per mile	$15,340
Counterweight about	6,000
Steel wire rope	2,000
Extra work at top and bottom of plane	1,500
Sheaves, frames, etc.	1,000
	25,840
For contingencies, etc.	7,160
	$33,000
Cost of supporting grade	66,000

The result of the above comparison may be briefly stated thus: Under the assumed data, the gravity plane is capable of doing twice the amount of work in the same time, while its original cost of construction is only one-half as much as an equivalent supporting grade.

It will be noticed that very liberal allowances have been made for delays at the head and foot of the incline, and for the friction of the gravity system. The friction of train, sheaves, etc., has been allowed for in determining the inclination. And the extra five tons weight of counterweight over that of the maximum train is not only sufficient to overcome any resistance due to curvature, but would render some assistance to the locomotive.

In conclusion, it may be added that in the construction of such a system due reference should be paid to the arrangement of the grades so that the maximum train, on that portion of the line which is arranged as a supporting grade, should be able to pass over the planes. Or the arrangement might be made with reference to the division of the trains at the foot of the planes, in which case it would be necessary to make two or more trips over the planes for each train.

THE RIVERS OF CHINA.

THE YANG-TSE, THE YELLOW RIVER, AND THE PEI-HO.*

From "Nature."

THESE three rivers form conjointly the great river system of China. Although at the present day each of them runs its separate course to the sea, there is good reason to believe that several centuries since they were united by a number of connecting branches, in a manner somewhat resembling the junction of the Ganges and the Brahmapootra in our own time. Such is the inference to be drawn from an ancient Chinese map, copied by Alvarez Semedo, a Portuguese Jesuit, and which must be assigned to a time preceding that of the construction of the Grand Canal by Ghenghis Khan in the beginning of the thirteenth century.† Linked together as these rivers were in the past, a brief consideration of their present condition will prove that they are laboring towards the same end in our own day. But before proceeding to examine them in their conjoint character, it will be necessary to consider briefly their leading hydrological features.

I.—The Yang-tse—the largest and most important of these three rivers—has a course of about 3,000 miles, and drains an area which is variously estimated between 750,000 and 550,000 square miles; for my own calculations I will adopt the mean of these two estimates, namely, 630,000 square miles. Its waters, commencing to rise in February and March, reach their highest level in the month of June or July; and here they remain with occasional fluctuations till the end of August or the beginning of September, finally reaching their lowest level towards the close of January.

With regard to the discharge of water of this river, Capt. Blakiston* has esti-

* The author, Surgeon H. B. Guppy, of H.M.S. "Hornet," writing from Yokohama, February 11, says: "I forward to you by this mail a paper containing the results of observations I have made during the last two years on the subject of the Yang-tse and the Pei-ho, together with similar information as regards the Yellow River. Looking on these three rivers as in reality one river system, I have embodied in one paper all the "data" concerning them; and have treated them both separately and in their conjoint character. I can answer for the accuracy of the various estimations, and have employed the usual methods in obtaining them."

† *Vide* a paper by Mr. S. Mossman on the "Double Delta of the Yellow River," published in the *Geographical Magazine* for April, 1878.

* "Five months on the Yang-tse."

mated the average amount carried past T-chang, which is situated at about 960 miles from the sea, at 500,000 cubic feet per second; he founded this estimate on observations made during the months of April and June. When stationed at Hankow in the winter 1877-78, a place distant about 600 miles from the sea, I set to work to make a similar estimate of the water carried past that city for the twelve months included between May 1877 and May 1878. Having taken a line of soundings across the river and having ascertained the river's breadth (1,450 yards by sextant measurement) at a point below the union of the Han with the main stream, I commenced a series of observations on the rise and fall of the river water and on the force of the current, which combined with information received from the Custom-house and from other sources, supplied me with the necessary data for my calculation. The results are contained in the following table:

1877.	Surface current. Knots per hour.	Average depth. Feet.	Water-discharge. Cubic feet per second.
May 31..	2¼ ..	64 ..	846,336
June 30..	2½ ..	61 ..	896,293
July 31..	3 ..	58 ..	1,022,656
Aug. 31..	3½ ..	62 ..	1,275,381
Sept. 30..	2¾ ..	63 ..	1,018,248
Oct. 31..	2 ..	53 ..	622,997
Nov. 30..	1¼ ..	42 ..	308,560
Dec. 31..	1 ..	36 ..	211,584
1878.			
Jan. 31..	¾ ..	30 ..	141,085
Feb. 28..	1⅓ ..	39 ..	412,620
Mch. 31..	1¼ ..	45 ..	396 720
Apl. 30..	2 ..	57 ..	670,016
			12)7,822,502
			651,875

We may therefore place the average water-discharge for the year at Hankow at 650,000 cubic feet per second. Now, estimating the area of drainage above Hankow to be about $\frac{11}{13}$ of the whole area, and assuming that the portion of the Yang-tse valley below Hankow drains off its waters at the same rate as the remainder of the river-basin, it follows that the average water-discharge for the whole river may be placed at 770,000 cubic feet per second.

With reference to the amount of sediment carried by the Yang-tse past the same city, I found as much as seven grains in the pint (nearly one drachm in the gallon) in the month of July, when the river was at its height; while in March, when the river was low, I found as little as three-fifths of a grain per pint. The average proportion of sediment during the twelve months in question I estimate at four grains in the pint (a little over half a drachm per gallon). This represents a proportion of $\frac{1}{2188}$ by "weight," or (taking the specific gravity of the dried mud at 1.9) of $\frac{1}{4157}$ by "bulk" of the average discharge of water. It is thus easy to obtain the total amount of sediment carried during the twelve months past Hankow, namely, 4,945,280,250 cubic feet: but to allow for the amount of mud a river pushes along its bed, one-tenth must be added according to the principle laid down by Messrs. Humphreys and Abbot in the case of the Mississippi. This will bring the total annual discharge of sediment at Hankow up to 5,439,808,275 cubic feet, or at the rate of 172 cubic feet per second. Now, assuming that the drainage area below Hankow supplies the same relative amount of sediment as the remainder of the catchment basin, I estimate the total amount carried down to the sea annually at 6,428,858,255 cubic feet.

The removal of this amount of sediment from an area of drainage of 650,000 square miles represents a lowering of the surface at the rate of one foot (of rock) in 3,707 years. This is therefore the rate of "subaërial denudation" of the valley of the Yang-tse as far as concerns the quantity of sediment removed. Of the proportion of solids in solution, I have had no opportunity of judging, but that the soluble matter is in considerable quantity is rendered probable from the extensive limestone districts traversed by this river.

II.—The Yellow River or the Hoang-ho has derived the appellation of "China's Sorrow" from its frequent destructive inundations. It runs a course of about 2,500 miles; but, unlike the Yang-tse, its lower course has frequently shifted in the course of ages, and although it opens at the present day into the Gulf of Pechili, only a quarter of a century has passed since it emptied its waters into the Yellow sea.* The mountainous district of the province or Shantung has in truth been the chief means in deflecting

* *Vide* Mr. Mossman's paper, already referred to.

the waters of this great river on more than one occasion during the historical era from the Gulf of Pe-chili to the Yellow Sea and vice-versa.

With reference to the quantity of water discharged by the Hoang-ho I have had no opportunity of personal observation. We have, however, an estimate not only of the water discharge, but also of the sediment, which Sir George Staunton supplies us in his account of Lord Macartney's embassy to China in 1792. It was calculated that at the place where the British embassy crossed the Yellow River—its junction with the Grand Canal—the water was carried past at the rate of 418,176,000 cubic feet per hour, or 116,000 cubic feet per second. The method employed in ascertaining the quantity of sediment was the measurement of the amount of mud deposited from a gallon and three-quarters of water when allowed to stand. From this experiment it was concluded that the sediment was in the proportion of $\frac{1}{200}$ of the original bulk of the water, and the annual discharge of sediment was assessed at 17,520,000,000 cubic feet.

However carefully these observations may have been made, and however near they may approach the actual discharge of water and of sediment at the time in question, it seems to me that one is hardly justified in accepting the result of a single observation as typical of the average state of things throughout the year; and yet Sir George Staunton's estimate has never, as far as I am aware of, been questioned. A single glance at the foregoing table will convince one of the little dependence that can be placed on a solitary estimation ; it will be there seen that the Yang-tse discharged nine times as much water when at its highest level in August as it did during the month of January, when its waters occupied their lowest level.* Or if the question of sediment is considered, to which the same objection would apply, I have the greatest diffidence in accepting Sir George Staunton's estimate as being of any value, except as a trustworthy result o a single experiment; and yet, even considered as the maximum of the whole year, the result is rather a startling one. While the greatest amount of sediment I found in the water of the Yang-tse was seven grains in the pint, and in the case of the Pei-ho—as will subsequently be noticed—fifteen grains in the pint, Sir George Staunton estimates the sediment of the Yellow River at over eighty grains in the same measure of water. Even the muddy waters of the Ganges do not contain more than twenty grains of sediment in the pint of water.

It is therefore not with any surprise that I find the "subaërial denudation" of the Hoang-ho is estimated* at less than half that of the Yang-tse, namely, one foot in 1,464 years. This estimate only refers to the amount of sediment removed, and yet I cannot but consider it as very liable to correction by some future observer. As this is the only calculation that has ever been made, as far as I am aware, with reference to the quantities of sediment and of water discharged by the Yellow River, I am perforce obliged to accept it as *pro tanto*.

III.—The Pei-ho drains the great plain which constitutes the province of Pe-chili. Its length is said to be about 300 miles, but the lower part of its course below the city of Tientsin is so tortuous that a distance of thirty miles overland is converted into fifty by the river. It is at Tientsin that the Pei-ho proper and the Yu-ho unite together to form the main stream; the latter is generally known by Europeans as the Grand Canal, but as a matter of fact the canal joins the Yu-ho about 150 miles to the southward. During the three winter months—December, January, and February—the Pei-ho is usually frozen over, the ice having a thickness of about eighteen inches ; in the same season there is generally a large quantity of ice in the Gulf of Pe-chili, which may completely fill up the head of the gulf.

With reference to the water discharge of this river, I was enabled while wintering at Tientsin during the season 1878-79, to collect some "data" for its estimation during the four months from December to March. Although my estimate strictly applies to but a third of the year, still from the limited rise and fall of the water during the different seasons (it never exceeds six feet) I feel pretty confident that it fairly represents the average rate of discharge during the whole

* In the case of the Ganges at Ghazepoor the proportion is as 1 to 14.

* *Vide Nature*, vol. 18, p. 288.

year. The breadth of the river at the place of observation below the city of Tientsin was 280 feet. The following table contains the results of my calculations:

1878.	Surface current. Knots per hour.	Average depth. Feet.	Water discharge. Cubic feet per second.
December	$1\frac{1}{6}$ ..	14 ..	6,355
1879.			
January..	$\frac{4}{5}$ ..	$14\frac{1}{2}$ ..	4,389
February.	$1\frac{3}{5}$ ..	16 ..	9,684
March. ..	2 ..	14 ..	10,592
			4) 31,020
			7,755

We may thus place the average discharge of water for the whole year at about 7,700 cubic feet per second.

Now with regard to the amount of sediment carried past the city of Tientsin: I found the average quantity during the four months in question to be about five grains per pint. (It varied much at different times, for I found as much as fifteen grains in the middle of March, while in the months of January and February it did not equal a grain in the pint.) This represents a proportion of $\frac{1}{1750}$ by "weight," or $\frac{1}{3325}$ by "bulk" of the average discharge of water; and following the same method of calculation as was employed in the case of the Yang-tse, I estimate the annual discharge of sediment for this river at 80,000,000 cubic feet.

Now the removal of this bulk of material from an area of drainage, which I estimate at 55,000 square miles, represents the lowering of the surface of one foot in 25,218 years. This is the rate of "subaerial denudation" of the Pei-ho basin, omitting of course the question of the solids in solution.

To show the rank that these three rivers hold in the fluvial system of the globe, I have subjoined a list of fourteen other rivers which gives the quantities of water and sediment discharged by each, as well as the rate of subaerial denudation, as far as I have been able to ascertain.

	Water discharged per second.	Sediment per annum.	Subaërial denudation.
	Cubic feet.*	Cubic feet.	
Amazon	2,458,026	——	——
Congo	1,800,000 (By Behm and Capt. Tuckey.)	——	——
Yang-tse	770,397 (By myself.)	6,428,800,000 (By myself.)	1 foot in 3,707 years. (By myself.)
Plate	700,000 (By Mr. Higgin and Mr. Bateman.)	1,543,500,000 (By Mr. Higgin.)	1 foot in 29,400 years. (Calculated from Mr. Higgin's estimate.)
Mississippi	618,000 (By Messrs. Humphreys and Abbot.)	7,474,000,000 (By Messrs. Humphreys and Abbot.)	1 foot in 6,000 years. (By Mr. Croll.)
Danube	300,321	1,255,500,000 (By Mr. Ch. Hartley.)	1 foot in 6,846 years.
Shat-el-Arab	295,461	——	——
Ganges, at Ghazpoor	203,485 (By the Rev. Mr. Everest.)	6,368,000,000 (By the Rev. Mr. Everest.)	1 foot in 2,358 years.
Indus	199,476	——	——
Atrato	185,274	——	——
Nile	130,032	——	——
Yellow River	116,000 (By Sir George Staunton.)	17,520,000,000 (By Sir George Staunton.)	1 foot in 1,464 years.
Rhone	91,935	594,000,000	1 foot in 1,528 years.
Rhine	69,741	——	——
Po	61,263	405,420,000 (By M. Lombardini.)	1 foot in 729 years.
Pei-ho	7,755 (By myself.)	80,000,000 (By myself.)	1 foot in 25,218 years.
Thames, at Kingston	2,300 (By Prof. Prestwich.)	1,865,900 (Huxley's "Physiography.")	1 foot in 9,600 years.† (Huxley's "Physiography.")

* Where not otherwise mentioned I have obtained my information of the discharge of water and sediment from the "Earth," by Elisee Reclus.

† This estimate also includes the solids held in solution.

We have now the necessary "data" for considering these three rivers in their conjoint character. Together they drain an area of 1,105,000 square miles; they discharge a body of water equal to 894,000 cubic feet every second; and they carry down every year to the sea 24,028,800,000* cubic feet of sediment, which represents a rate of subaerial denudation equal to the removal of one foot of solid rock in 1,687 years.

If we look upon the Yang-tse, the Yellow River, and the Pei-ho as laboring, with the assistance of the gradual elevation of the sea border, which is at present going on, to extend the territory of China seaward towards her ancient coast-line—represented by a line running from Kamtschatka through the Kurile Islands, Japan, the Loo-choo group, Formosa, down to the Malay Archipelago; † and carry ourselves forward into the future when such task is completed and the waves of the Pacific beat once more against this old sea border, we shall not have much difficulty in picturing to ourselves what will then be the state of matters. In the place of the gulf of Pe-chili and the Yellow Sea there will be vast alluvial plains traversed by the waters of the Yang-tse, the Yellow River, and the Pei-ho; but before the ancient coast line is reached they will have joined to form one great river and one united delta. If the Yellow River confines itself mostly in future ages to its course into the gulf of Pe-chili, that gulf will be filled up in process of time; and the Hoang-ho winding along through the bed of this obliterated sea will, after being joined by the Pei-ho, turn its course southward, deflected by the Corean peninsula, until it meets at length its sister stream. On the other hand, should the Yellow River be mostly occupied in future in advancing its southern delta it will join the Yang-tse at a period much less remote from the present; and their united waters will pursue an easterly direction subsequently to be joined by the Pei-ho, which will have been gradually finding its way through the gulf of Pe-chili and the Yellow Sea during the preceding ages. In either event the union of these three rivers would follow.

Such being the case, it may be interesting to speculate on the time required by these rivers to fill up the seas into which they discharge their sediment. Sir George Staunton estimated that at the rate the Hoang-ho was discharging sediment it would fill up the Yellow Sea and the gulfs of Pe-chili and Lian Tung in 24,000 years; but M. Elisée Reclus is of opinion that this estimate ought to be doubled, as the Yellow Sea is much deeper than Sir George Staunton stated it to be (20 fathoms). On carefully examining the latest charts of these seas I am inclined to consider that this estimate cannot be assailed on this point, as my own determination of the average depth is 22 fathoms.

We will now attempt to gauge the the time that the three rivers in question would require to fill up, by the sediment they deposit the portion of the sea which is included by the gulfs of Pe-chili and Lian Tung, the Yellow Sea, and the Eastern Sea north of the 29th parallel and west of the 126th meridian. I have placed the total surface area at 200,000 English square miles, and the average depth at 26 fathoms; and following Sir George Staunton's mode of estimation I find that it would take sixty-six days to form an island a mile square reaching up to the surface of the sea. At this rate it would require 36,000 years to form all the sea in question into dry land, supposing of course that there was no elevation or depression of the sea-bottom during that period. But the recent formation of several islands and shoals in the Yang-tse estuary, the occurrence of raised beaches and marine remains at Hang-chau, Wusung, and Chefoo, with other similar evidences, demonstrate that there is an elevation of the coast going on at present; and, in that case, it will require considerably less than 36,000 years to form the sea into *terra firma*.

Perhaps Sir George Staunton's original estimate for the Yellow River may not be far wrong when applied to the whole sea in question.

* In "Page's Advanced Text-book of Geology," Staunton's estimate of the sediment discharged by the Yellow River has been erroneously applied to all "the great Chinese rivers."

† Vide a paper on this subject, by Mr. A. S. Bickmore, read before the North China branch of the Asiatic Society in November, 1867.

In Western Australia the construction of a telegraph line to Roeburne is under consideration.

THE PRINCIPLES INVOLVED IN THE CONSTRUCTION OF THE TELESCOPE.

By THOMAS NOLAN, B. S.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

I

The Telescope is certainly one of the noblest monuments of human genius, and its invention will always be considered as among the most remarkable in the whole circle of human knowledge. It is a work, in which, by following unconsciously the plan of nature in the formation of the eye, we have come the nearest to the construction of a new organ of sense, and by means of which, we have extended our views and researches far beyond the limits of our own globe—that sphere which nature seemed to have designed for our inquiries. Enabling us to penetrate into the immensity of space, and to become, as it were, familiar with other worlds placed at almost immeasurable distances from us, the telescope has revealed an infinitude of celestial bodies, whose existence must forever have remained unknown to us, but for its invention. Its history, like that of every complicated instrument, has been a history of improvements. The question of the origin of the invention, although abundantly inquired into, has never met with a satisfactory answer; and the question—who made the first telescope? will probably never be conclusively settled. For the invention, in its original form, we are indebted to accident, or to the trials of men who had little knowledge of the principles of the science upon which they were conferring so great a favor. Not a single thing, but a combination of things, the telescope in its earliest forms was a simple combination of certain kinds of convex and concave lenses, known and used as spectacles many years before; and whether the credit of the invention should be given to Metius, Lipperhey, Jansen, Baptista Porta, Galileo, or to others whose names are unknown, it is a most difficult and invidious task to decide. But interesting though these inquiries may be, it is not my purpose in this dissertation to enter into the discussion of the question as to who was the inventor of the first "optick-tube," or to describe minutely and historically all the several successive changes and improvements which it has undergone in the hands of different philosophers; but rather, to examine the theory of those forms of refracting and reflecting telescopes which have been of more general application.

THE OPTICAL PRINCIPLES INVOLVED IN THE CONSTRUCTION OF THE TELESCOPE.

A telescope, in general, consists of a tube containing a system of glass lenses, or a speculum in combination with such lenses; and is used to render distant objects more clearly visible; (1) by enlarging their apparent angular dimensions, and (2) by introducing into the eye a superior quantity of their light.

Those constructed with glass lenses only, are called dioptric or refracting, and the others catoptric or reflecting telescopes. In the refracting telescope, rays of light coming from the object are made to converge by a convex lens, and, if not intercepted, form an image at its focus. In the reflecting telescope, the image is formed by the reflection of the rays which impinge upon upon the concave surface of a speculum.

We will first consider,

I. THE SIMPLE REFRACTING TELESCOPE.

In exhibiting the principles on which the refracting telescope is constructed, we must first explain the formation of the image of an object at the focus of a lens.

When a convex lens is placed before an object, an image of the latter is formed at a certain distance behind or before the refracting surface, whose magnitude is greater or less, according as it is formed farther from, or nearer to the

surface. The one particular distance at which the image is distinct, is called the focus. At every other distance it is hazy and confused. By the use of the telescope the image is produced on the retina of the eye itself, and its office is to prepare the rays of light for forming on the retina an image larger and clearer than would be formed without its help.

In (Fig. 1) two rays proceeding from

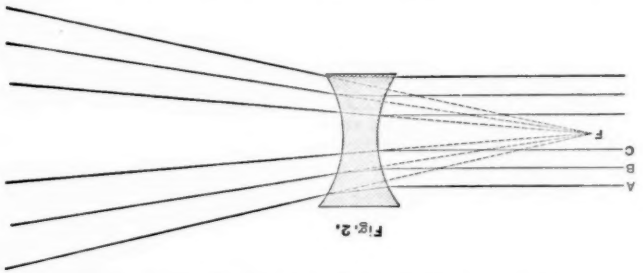


Fig. 2.

the top and bottom of the object AB are represented separately. The ray A*a*, passing through the center of the lens O, is unaffected, because the surfaces through which it passes are parallel to each other, and from the property of the lens, all other rays from A, on passing through it, are brought to a focus somewhere on A*a*, depending upon the curvature of the lens. In like manner, all rays from B are brought to a focus at *b*, each point of AB having its corresponding focus in *ab*. The latter is smaller than AB in proportion as *c*O is less than CO; and if we increase the focal length of O till *ab* is twice the distance away, it becomes double its present size. The place of an image depends upon the distance of an object, and when the latter is considered at an infinite distance, as is the case with the heavenly bodies, the image is formed at the principal focus of the lens, or the focus of parallel ray.

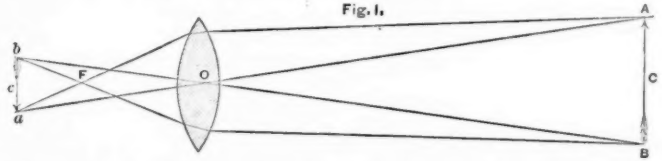
If rays ABC &c., pass through a concave lens, as in (Fig. 2), they are not brought to a focus, but diverge as if they came from some point F, called the virtual focus.

The first condition which a telescope must fulfill is, that it shall so dispose all rays emanating from any point in an object, that they may emerge from the instrument parallel to each other, in the usual or medium situation of the mechanism.

The second condition is, that the mechanism itself shall be adjustable, so as, by a movement of the parts *inter se*, to convert this parallelism into a slight divergence or convergence, to suit the eyes of near or long-sighted persons.

The third condition is, that the pencils of parallel rays coming into the eye from different points of the object, shall be inclined to each other at greater angles than those actually subtended at the eye, by the respective intervals between the points themselves. The number ex-

Fig. 1.



pressing this ratio is the measure of the *magnifying power* of the telescope, and the *apparent linear dimensions* of an object being in proportion to its magnifying power, the apparent enlargement of its *superficial area* is as the square of the magnifying power.

The simplest construction of the refracting telescope is that in which the image formed in the focus of a convex lens, or *object-glass*, is viewed through a second lens, or *eye-glass*, so placed as to have the image in its focus for parallel rays incident in the contrary direction,

and its axis coincident with that of the first lens.

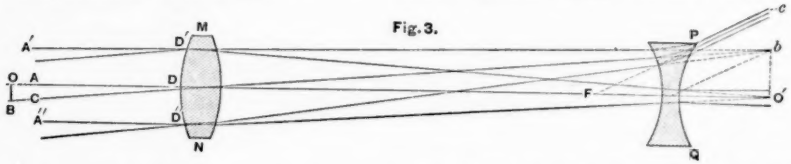
Three cases arise by applying this principle, which afford telescopes of different characters:

1. The *Galilean telescope*, with double concave eye-glass, showing objects erect.

2. The *Astronomical telescope*, first suggested by Kepler, with double convex eye-glass, showing objects inverted.

3. The *Terrestrial telescope*, suggested by Rheita, with three double convex eye-glasses, showing objects erect.

Fig. 3.



1. THE GALILEAN TELESCOPE.

In this instrument, the eye-glass PQ (Fig. 3) is placed between the object-glass MN and its focus O′, so that the axes of both glasses are in the same line AO′, and their foci in the same point O′.

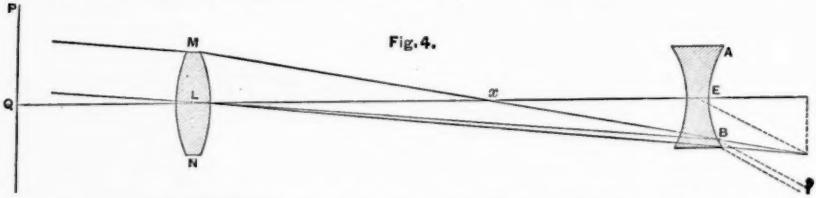
(1.) The object OB being supposed infinitely distant, incident parallel rays, as AD, A′D′, A″D″, are first rendered converging towards O′ by MN, and afterwards parallel by PQ. They are also much denser than before their first refraction, and, when received by the eye, paint an image of the object, so much the more vivid, as the density of the pencil of rays is then greater than before it fell upon MN.

(2.) The point B sends forth parallel rays as CD and its two parallels, which are refracted towards some point *b*, and then rendered parallel by PQ. Since this pencil, in emerging from PQ, diverges from that formed by the point O, a greater number of the parts of the object will be seen as the eye is placed nearer to PQ, and as the pupil is more dilated. But since the dilation of the pupil is small, and since it involuntarily contracts in proportion to the quantity of light impinging upon the eye, the field of view is so much the less as the focus of PQ is greater.

(3.) Since the nature of light will not admit of an eye-glass whose focus is diminished beyond a certain limit, and since the focus ought to be longer in proportion to the length of the focus of the object-glass, the field of view will be less the greater the length of the instrument, which inconvenience, together with those above described, render this instrument almost useless for purposes of astronomical observation.

(4.) The pencil of rays *c*, from B, under the axis, meets the eye in the direction *c*F, answering to a point also below the axis; and in the same manner, a ray issuing from any point of the object, above the axis, has a similar direction on emerging from the eye-glass. Consequently, objects and their images have like positions with respect to direction, when viewed through a telescope of this construction.

Fig. 4.



(5.) To determine the field of view, we let MN (Fig. 4) be the diameter of the object-glass, AB that of the pupil of the eye whose center is in the axis of the telescope, and join M and B, the opposite extremities of these diameters, and let MB meet the axis in *x*, and the image in *p*. We draw also LB and L*p*, and suppose *p*L and *q*L to be produced till they meet the object in P and Q. PM is refracted to the pupil in the direction MB, but every other ray in the pencil, as PL, and every ray which

comes from a point more distant from the axis, falls below the pupil. Therefore, PQ is half the linear magnitude of the greatest visible area. QP is measured by the angle QLP, or by its equal qLp.

$qLp = ELB + BLp$, and

$$BLp = LBM - LpM.$$

$$\therefore\ qLp = ELB + LBM - LpM.$$

And 2QP is measured by

$$2ELB + 2LBM - 2LpM.$$

That is, the linear magnitude of the field of view is measured by the angle which the diameter of the pupil subtends at the center of the object-glass, increased by the difference between the angles which the diameter of the object-glass subtends at the pupil and at the image.

2. THE "ASTRONOMICAL" TELESCOPE.

This instrument, represented in (Fig. 5) differs from the Galilean, in having a convex instead of a concave eye-lens, which is so placed with regard to the object-glass that their foci coincide in the axis of the telescope between the two glasses, instead of being beyond the eye-glass as in the Galilean telescope. PQ is the eye-glass, MN the object-glass, KD the axis, and o the common focus.

(1.) The rays AD, A′D′, A″D″ from O in the object OB, infinitely distant, are refracted to the focus o where they form an image of O.

(2.) This image o is considered as an object placed in the focus PQ, and rays diverging from o, and falling on PQ emerge parallel to each other, and are so much the more dense as the focal length of PQ is less than that of MN. They therefore paint on the retina a new image of O, which is so much the more vivid, as the surface of MN is greater—that is, as it admits a greater quantity of light.

(3.) Rays from B form in b, an image of this point, and falling afterwards on PQ, emerge parallel and more inclined to

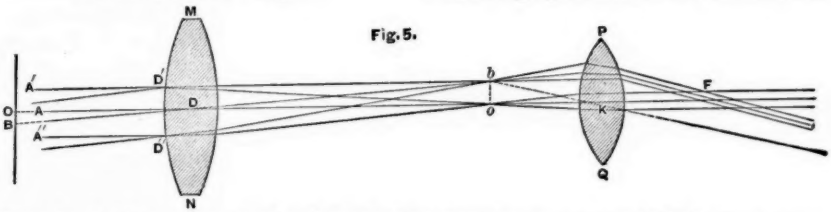


Fig. 5.

AF as the curvature of PQ is greater; so that the axis of the pencil which they form, cuts the common axis of the two lenses in F, the focus of PQ. Consequently, to see all of ob at the same time, the eye must be placed at F, the common intersection of all rays emitted from each point of ob, or of OB.

(4.) b, the image of B, is refracted to the eye in the direction PF, and has a different direction from that in which it is emitted from B; and the ray which renders visible a point above the axis

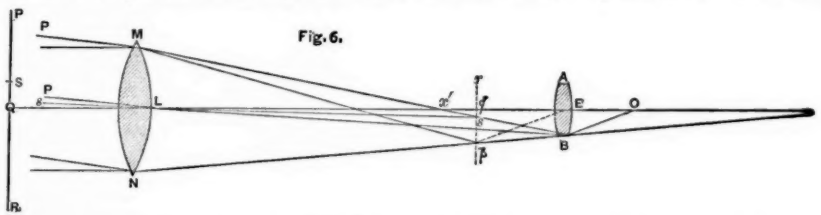


Fig. 6.

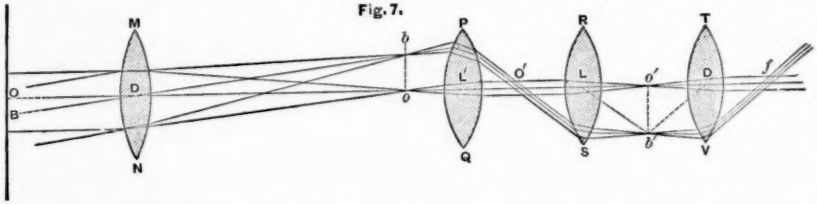
reaches the eye as if it proceeded from below the axis; and thus the entire image is reversed.

(5.) To find the field of view, we let MN (Fig. 6) be the diameter of the object-glass, AB that of the eye-glass, and draw NB, letting it cut the image pqr in p. We draw also pL, and conceive pL and EL to be produced until they meet the object in P and Q; and draw pE and NP, and also BO parallel to pE. Then the eye at O receives the ray NBO, which comes from a point in the object at

the greatest visible distance from the axis of the telescope. For rays from any point above P, converge to a point below *p*, and fall below AB; consequently P is the exteme visible point in the object, and QP is half the linear magnitude of the visible area.

(6.) To find the *brightest area*, we draw MB cutting *pqr* in *s*, and the axis LE in *x'*, and draw L*s*, and conceive it produced till it meet the object in S. Then, (*a*) if *x'*E be greater than *q*E, all rays from S falling upon MN, are refracted to AB; for, SM is refracted in the direction M*s*B, and any other ray of the pencil, as SL, crosses MB at *s*, and falls somewhere between A and B. In like manner, rays from any point between S and Q, are refracted to AB. (*b*) If *x* and *q* coincide, the brightness of the field increases to the center. (*c*) If *q* *fall between* L and *x'*, all the rays belonging to any one pencil incident upon MN, are not received by AB.

Fig. 7.



3. THE TERRESTRIAL TELESCOPE.

The nature of this construction is easily comprehended by reference to (Fig. 7). The four lenses have one common axis A *f*. and each contiguous two are so situated that their foci coincide. If OB be an infinitely distant object, the parallel rays from O, in the axis produced, from an image in the focus *o*, whence, falling on, PQ they emerge parallel to each other and to the axis. Falling upon RS, they are refracted to the focus *o'*, where a second image is formed, and then diverging, and falling on TV, they are refracted to the eye in directions parallel to the axis. In like manner, rays from B form in *b* an image of that point, whence, falling in PQ they are rendered parallel to each other, but oblique to the axis till they meet RS, by which they refracted to the second focus *b'*; whence, falling on TV, they are again rendered parallel to each other, but so inclined to the axis as to meet it again with all the other rays in the focus *f*, where the eye is placed to receive the final impression, which is that of an image corresponding, as to its direction, with the object itself. For the ray *b'*V*f*, which carries the image of the point B, has a similar direction with respect to the axis, as the ray proceeding immediately from B.

As the properties of this instrument are analogous to those of the astronomical telescope, it is unnecessary to enter into further discussion of the principles of its construction.

FILTRATION THROUGH SPONGY IRON.

From "Engineering."

It is now some years since Mr. Gustav Bischof demonstrated the remarkable properties of spongy iron as a filtering material for the purification of water for drinking purposes, and spongy iron filters are already in extensive use for domestic purposes. Notwithstanding this, however, and notwithstanding also the testimony to the powers of spongy iron which has been afforded in the sixth report of the Royal Commission on Rivers Pollution, in the reports of the Registrar General, in the Army Medical Report for 1877, and elsewhere, the material has not yet been employed on a large scale for the filtration of water at any of our water works, a fact which is to be regretted when the remarkable effect of the material on Thames water is taken into consideration.

Although, however, spongy iron has not yet been introduced at water works

in this country, it is, we understand, about to be employed by Messrs. Easton and Anderson for the filters at the Antwerp Water Works, which they are now in course of construction. To determine the suitability of the spongy iron for effectually dealing with the Nethe water which is to be used for the supply of Antwerp, Messrs. Easton and Anderson have recently carried out a series of experiments on a considerable scale, and these have yielded results of much interest. The arrangement employed consisted of two cast-iron tanks, each having a horizontal area of 342 square feet, while the one was about 11 ft. and the other 7½ ft. in depth. In the larger tank there was placed on a suitably constructed brick bottom, a depth of 3 ft. of spongy iron and gravel mixed in the proportion of 1 to 3, while above this was placed a bed of Harwich sand 18 in. in thickness. From the bottom of this filtering tank, the water was drawn off to the second tank, this latter containing, as filtering material, a bed of gravel about a foot thick with 2 ft. of Harwich sand above.

The object of the second filter is as follows: In passing through the spongy iron a small quantity of iron is dissolved in the form of protoxide, and if not removed it would, when converted into peroxide by the contact of the water with the air, be thrown down in the form of a brownish deposit. In the spongy iron filters for domestic use the further oxidation of the protoxide is effected by an admixture of manganese binoxide, the peroxide of iron being thus formed and retained in the filtering material. This use of the manganese binoxide would not be convenient on a large scale, and in the arrangement we are describing the water after passing through the spongy iron in the first tank is allowed to come in contact with the air in the second tank, when the peroxide of iron is thrown down and arrested by the filtering material which that tank contains, thus allowing the water to be delivered perfectly clear.

With the arrangement we have described, Messrs. Easton and Anderson found that they could efficiently filter the Nethe water at the rate of 150 gallons per square foot of filtering surface per 24 hours, or 6¼ gallons per square foot per hour. At the Metropolitan Water Works the rate of filtration with the ordinary filter beds varies from about 1⅓ gallons per square foot per hour in the case of the East London and the West Middlesex Works to as much as 4 gallons in the case of the Lambeth Works, but the average rate for all the works is decidedly under 2 gallons per square foot per hour, so that the results which Messrs. Easton and Anderson have obtained with spongy iron, and with a water greatly in need of filtration, point to the possibility of employing filter beds very materially smaller than those ordinarily necessary.

So far as experience at present goes, the spongy iron in filters requires no renewal. Its action appears to be to produce an oxidation of the organic matters in the waters traversing it, the result being a discharge from time to time of carbonic-dioxide. We have referred to the testimony of the Registrar General to the effect of spongy iron, and we cannot do better than quote from his report for 1877 the following paragraph respecting it. He says: "The Thames was in high flood during nearly the whole of December, and its water was loaded with organic impurities of the most disgusting origin. It may be interesting to those who can afford the cost of domestic filters, to know that even this polluted water can be *chemically* purified by filtration through spongy iron. I have inserted in the analytical table, for the purpose of comparison, the results yielded by the Grand Junction Company's water, after passing through a spongy iron filter, which had been in use for more than a year. The filter removed nearly nine-tenths of the organic matter, and more than one-half of the hardness from the water." The table here referred to is annexed, the quantities being given in parts per 100,000.

The manufacture of spongy iron on a large scale is an interesting process, and we may hereafter have something to say concerning it. Meanwhile, however, we may state that Mr. Bischof has taken Dr. Siemens' well-known experimental works at Towcaster, and is making spongy iron there in the Siemens revolving furnace, which has proved admirably adapted for the purpose. Considering the results which have been gained with domestic filters, and the promising data

Description of Samples.	Temperature C.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness.
Water supplied by Grand Junction Company.....	9.7	28.36	.380	.074	.001	.265	.340	2340	1.65	18.0
Same after filtration through spongy iron....	..	14.70	.038	.012	.010	.128	.148	1040	1.70	8.1
Supply of the Kent Company.....	13.5	37.50	.048	.012	0	.368	.380	3360	2.30	25.5

afforded by Messrs. Easton and Anderson's experiments at Antwerp, the application of the system of spongy iron filtration at the Antwerp Water Works will be watched with much interest, and we hope in due time to be able to place full information regarding the results before our readers.

WEIGHT IN LOCOMOTIVE CONSTRUCTION.

From "The Engineer."

THE "Links in the History of the Locomotive," which we publish from time to time as we succeed in picking them up, even if worked into a continuous chain, extending from 1829 to 1880, would be complete only for a day or a month. At the end of some such period a new type of engine would be built, and a new link would have to be added to the chain. Put in another way it may be stated that locomotive engine construction is a thing of continual progress. It is difficult, indeed, to find any branch of mechanical engineering in which changes in design, and form, and proportion, so rapidly succeed each other. There is not a railway in the kingdom which is now worked by engines of precisely the same pattern as those in favor ten or even five years ago, and it is to be assumed that novel types are adopted not simply for the sake of change, but because some advantages are supposed to be gained. A glance at the direction which progress in locomotive construction is taking may not be found uninteresting.

The most prominent feature in the modern British locomotive of the most improved type is its great weight. English and Scotch locomotive superintendents have gone on year by year making their engines heavier and heavier, and we have no reason whatever to think that finality has been reached in this direction. Locomotives are not made heavier for the sake of securing adhesion alone, but in order to secure immunity from breaking down. In other words, they are made much stronger than they used to be. Thin boilers, and frame plates seven-eighths of an inch thick, have given place to $1\frac{1}{8}$ in. plates; cylinder castings are heavier, motion bars have increased dimensions, pins are made larger. In short, engines are made stronger all over than they were made a few years ago, and for the same reason they have risen from a maximum weight of 30 tons or thereabouts to a maximum of 36 tons, or even more. We speak now of tender engines. In tank engines the change is still more marked; up to about fifteen years ago a tank engine which weighed more than 30 tons was an exception. At the present moment there are bogie tank engines working the Tilbury and Southend Railway which we understand weigh 56 tons in running order. Mr. Kirtley's Crystal Palace tank engines weigh about 50 tons in working order, and various other examples of heavy engines could be cited. We may be excused, perhaps, if we digress here for a moment, to say that it is by no means easy either to escertain

the weight of an engine in working order or the distribution of weight on the wheels. Locomotive superintendents do not always possess the means of weighing their engines as a whole, and they even less often can weigh them wheel by wheel. For this reason rather vague statements get into circulation, some of which are not quite true, while others may be true. We recently heard it asserted, for example, that 8ft. driving wheels of the single outside cylinder engines of the Great Northern Railway carry 19 tons or a little over now, or about four tons more than they did at first, as they were found to lack adhesion. The extra weight has been obtained, of course, by a readjustment of the springs. Whatever uncertainty may exist as to precise weights, there can, however, be no doubt that, as we have said, weight has, on the whole, augmented and is augmenting. Not a few experienced locomotive superintendents hold that we are in this respect progressing in the wrong direction, and that engines are now made heavier than they need be made, and that just as good results could be obtained from lighter machines. The question ought to admit of being readily settled. The modern engine is in many cases called upon to do more work and harder work than its predecessors. This may be granted, but it is by no means clear that it must be made heavier to enable it to do this additional duty. The adoption of steel rails opened up new possibilities to the locomotive designer, and he has not been slow to avail himself of his chances; but we may ask, what has really been gained in this way? Locomotive improvement means less first cost or less cost for repairs, or less cost for fuel or more hauling power. Is it certain that increased weight will entail any one of the advantages we have named? We think not. One man builds an engine with 17in. cylinders, 24in. stroke, and 1100ft. of heating surface, which weighs 28 tons; another man builds an engine with the same stroke and cylinder and heating surface, and it weighs 34 tons. Does it follow that the last must be the best engine of the two? We doubt it. The difference between them will probably be very small. They will both be four-coupled, one will have 6ft. and the other 6ft. 6in. drivers, perhaps, but the hauling power of both will be practically the same, and in the long run it will, we venture to think, be found that the light engine will not require more repairs than the heavier engine. It may seem a hard thing to say—and we say it with some reluctance—that the modern designers of locomotives do not manifest as much ingenuity of skill in scheming as those who have gone before them. The locomotive superintendents of to-day have an enormous stock of accumulated knowledge to draw upon, which was not possessed by the men of the last generation, and they have, besides, tools and materials of the highest perfection, and there are comparatively few demands made on their inventive powers. The best features in the modern locomotive are its simplicity and its workmanship. The display of a little more originality would, we have no doubt, materially improve the engine. The essence of success lies in putting weight into the right place, and in so disposing our materials that they may be loaded and worked to the best advantage. In this way a great deal of weight may be saved. Let us cite as an example of what we mean, the staying of fire-box crowns. The bridge stays for a fire box will weigh with studs, nuts, etc., 15 cwt. or 16 cwt. We have heard of cases in which they weighed 30 cwt. The weight of vertical sling stays, doing the same work much better, would not exceed 5 cwt. or 6 cwt.

It should by this time be well known that engines have to go into the shops for repairs to wearing surfaces more frequently than for any other cause. Axle brasses and axles are a fruitful source of trouble, and it is much to be regretted that all railway lines are not laid for a gauge of 5 ft. This would have given 3½ inches more space for bearings. Four bearings would have been improved, namely, the two crank pins and the two crank shaft journals. The two first could have each been made about 4¼ inches long instead of 3½ inches, and the latter could have been about 8 inches, or even a little more, instead of 7 inches. To get increased surface in these bearings should be the great aim of the engineers' life; if he can succeed he will keep his engines out of the sheds. Mr. Webb is apparently more fully impressed

with the importance of this truth than any other engineer in Great Britain, and it is for this reason that Joy's valve gear promises to prove so valuable. There is much about Mr. Webb's practice of which we cannot approve, and he is content with a want of finish and style in his work which is not paralled on any great railway in Great Britain; but we willingly concede that he does not waste metal, and that he knows as well as any man living just what to put in a locomotive, and no engineer better understands what are the causes which send locomotives into the shops, and how best to deal with those causes. There is we fear a tendency among too many designers of locomotive engines to produce something which shall be grand and imposing, and this is accompanied by a certain degree of carlessness concerning the effect which an engine may produce on permanent way. Nor is there quite so much solicitude to keep down repair expenses as desirable. When everything has been made very big and very strong, and very heavy, the designer fancies he has done all that is needed; and if his engines make but 12,000 or 14,000 miles in the year he does not take himself to task; and yet had a little more care been taken to make the proper things big and nothing else, weight might have been kept down, first cost reduced, and the staying powers of the engine greatly increased. We hear every now and then of engines which have made their 90,000 miles or so without going into the shops for repairs. We heard only a few days since of an engine which had made 251,000 miles. If we examine them we shall find that the secret of their success lies in large bearing surfaces, efficient lubrication, and the disposition of metal in the proper place. We are writing now not for the experienced locomotive superintendent, who fully recognize the truth of what we are saying, and for whom indeed we speak, but for younger and less experienced men, and these cannot too strongly impress on their minds the truth that weight as weight is as a rule objectionable in a locomotive; and that it cannot be made to compensate for want of care and skill in proportioning the various parts of the whole machine to the discharge of the special duties to be porformed by each.

The augmentation in the weight of the modern British locomotive with which we have been dealing is due in same measure to the extended adoption of the bogie. It was originally invented in this country, and went thence to the United States. Here the earlier lines—like the Manchester and Liverpool, the London and Birmingham, and the Great Western —were nearly level and very straight. On such roads the bogie was a superfluity, augmenting weight and doing no good ; but in the United States matters were different. Their roads were bad, steep, and crooked ; rigid engines could not traverse them, and speeds were slow, so bogies carried the leading ends of the engines and balance beams the trailing ends. In process of time we began to make crooked and hilly roads, and it was found advisable to adopt the bogie, which is rapidly growing in favor in this country. It is now in use on the Midland, the North British, the Lancashire and Yorkshire, the Great Northern, the North-Eastern, the London, Chatham, and Dover, the London and Brighton, and many other important railways in Great Britain. Equalizing beams are not so much in favor. It is not easy to say why. Mr. D. K. Clark's dictum that they make an engine unsteady did much at one time to stop their adoption, and they have not since increased in favor. They are, however, in use on several lines. The London, Chatham, and Dover and the Metropolitan Railways may be cited as examples. The bogie is no doubt of value in saving permanent way, because it consolidates it and brings it to its bearings before the heavily loaded wheels reach any given spot ; but the bogie is by no means free from defects. It adds a good deal, as we have said, to the weight of a locomotive, and yet more to its first cost. It is a noteworthy circumstance, that as our railways departed from the original perfection given to them by such men as Brunel and Stephenson, and we have adopted the bogie, so in the United States, since track has been improved there a tendency has grown up to abandon the bogie and adopt the English system. The change has begun with cars. Experiments have been made which show that the resistance of bogies with a very short wheel base is much greater than that of bogies with

the axles far apart ; and four-wheeled goods wagons of the English type are now being tried on American lines, and we have very little doubt that locomotives without bogies will soon be built. Some of the Pullman cars are carried by bogies with six wheels in each, and a wheel base of about 15ft., and it is obvious that if these can get round the curves met with a locomotive properly designed and without any bogie can have no difficulty. It is also noteworthy that American engineers are following English practice in another respect, and are building locomotives with one pair of driving wheels only—a thing hitherto unheard of in the United States.

We have said that weight is objectionable in locomotives, and we feel that it is necessary before concluding to explain precisely what we mean, for so far as adhesion is concerned a locomotive cannot weigh too much, and the heavier it is the better. But the locomotive and the permanent way ought always to be regarded as parts of a whole; just as much one with each other as the table of a planing machine and the V grooves which carry it. As regards the rails, the lighter an engine can be made the better. Now, if the locomotive superintendent did all in his power to keep down weight, he could not get rid of it so far as to reduce the efficiency of a four-coupled engine. He might, it is true, diminish the hauling powers of a single engine; but as these have or ought to have in all cases large driving wheels, their power of pulling is never very great. Of the five or six tons unnecessary weight now and then put into an engine, only a portion reaches the driving wheels, and it will be generally found that a four-coupled engine which weighs more than 30 tons is very severe on the road, unless it has a bogie; nominally 30 tons means 5 tons a wheel, not too much for a steel rail; really it means 7 tons or even 8 tons per wheel on one pair of wheels, which is too much. In practice it will not be found, we repeat, practicable to make a four-coupled engine too light, but it will be very easy to make it too heavy by putting metal where it is not wanted. Every engine is too heavy which possesses more weight than just enough to enable it to perform its work with efficiency. Drivers, we know, like heavy engines, because they do not slip in bad weather; but a few pounds of sand will as a rule do the work of some tons of iron, and much better, and locomotive superintendents should not permit themselves to be too much guided by the utterances of their men. The American engineers first taught us the real value of sand, and Mr. Adams, when on the North London Railway, showed us how to use it. A little consideration should be shown for permanent way. Working expenses have of late been increasing on all our railways, and it is worth considering whether some of this augmentation may not be due to the growing use of heavier and heavier engines. It may be that the demands of traffic are so importunate that they cannot be dispensed with, yet the running of 20 or 25 ton locomotives over 75 lb. steel rails presents a tempting picture. Such a road under such engines, once made, ought to last almost for ever; we cannot have 20 ton engines, but the nearer we can keep to that weight the better for the road and the shareholders.

BRICKS AND THEIR HISTORICAL INTEREST.

From "The Builder."

In the antiquity of the brick as a building material it is needless, nor is it indeed our intention, to insist. The great national collections of Europe, the British Museum foremost in the number, show us bricks, sun dried and baked, from the ruins of Nineveh, and from the days of that city to the present moment bricks have never ceased to be an important instrument in the hands of the builder. That throughout Asia Minor they were largely employed we have seen, only very recently, proved in these columns ; M. Rayet, in his work on Miletus, having shown that the far-famed palace of Crœsus was built of no more costly materials than honest bricks. What those bricks were, and their quality, are even

to this day appreciated by the natives, who for many centuries, have plundered the ruins to build or to patch up their own even more ruinous houses. The use of bricks among the Romans, who largely employed them as building materials, as we see in the familiar instance of the Temple of Concord, has been more than once the subject of the inquiry of industrious antiquaries, for the Romans were not content with producing the flat, tile-like brick which is so often to be met with in the lower portions of antique structures scattered over the Empire, and that are known in England, but their bricks were indelibly stamped with the mark of their maker, the names of the reigning consuls, and sometimes the year. From this source, then, more than one patient archæologist has gathered a rich store of information. But few inquirers have ventured far on the apparently arid and difficult road, which has hence remained little explored. Some curious information has, however, been lately thrown on the question by the researches of a French antiquary, M. Descemet, who has published in a recent number of the *Bibliothèque des écoles d' Athènes et de Rome*—an excellent publication, founded in 1877 and now at its seventeenth number—an article on the "Inscriptions doliaires latines" or Roman brick-marks, more especially relative to the *gens Domitia*, in antique Rome the most renowned brick-makers.

From an epigraphical point of view the brick marks of the Romans have aroused the attention of more than one archæologist, but the difficulties which have stood in the way of procuring the stamps, added to the enigmatical nature of the inscriptions themselves, have led the inquirers to fields where the results were more showy and more easily obtained. M. Descemet has long been known to the antiquarian world; as far back as 1857 his "Fouilles de St. Sabina" attracted no little attention, as also, in 1876, his study, "Sur quelques Regles de Briques antiques," published in the *Bulletin de Correspondence Archæologique*. In possession of a valuable collection of stamps of his own, together with copies from the brick stamps of the Vatican Museum, M. Descemet had at his disposition more than ordinary sources of reference, and the result of his study has been the work the title of which is above given.

The Italian antiquaries of the seventeenth and eighteenth centuries, Nardini, Ciampini, and their contemporaries, had not largely drawn on the store of historical information afforded by the Latin brick inscriptions; Fabretti was, indeed, the first to set into any order the more remarkable of these, but his efforts were merely tentable; his collection of inscriptions was unclassified and incomplete. It was reserved to the worthy Abate Gaetano Marini, the curator of the Vatican Museum at the close of the last century, to put together in a methodical manner the stamped bricks of the choice collection under his control; this task he admirably performed, preparing a learned catalogue which however remained at his death in an incomplete and manuscript form; but, such as it is, this manuscript preserved in the Vatican Library, has proved a mine of information to all subsequent writers. Marini's catalogue was arranged with admirable order and carefully classified, each brick of the collection being the subject of numerous commentaries.

In spite of Marini's method, M. Descemet has adopted another system more suited to the requirements of the day, as rendered necessary by the considerable additions made to the list of brick inscriptions since the recent excavations. In his introduction, M. Descemet has carefully shown the importance of the study of these brick inscriptions, by which the date of the erection of a building may be approximately ascertained. But as the author hastens to add, the fact of bricks bearing dates, or stamps being found in certain spots, is not, of course, conclusive evidence to the archæologist. Thus, in 1844, at Aix, in Provence, a brick of the year 123 was found, stamped with the mark of a Roman workshop, but the presence of this brick can alone be accounted for by the effect of accident, as it was scarcely possible that a town near Marseilles, so long famous for its pottery, should receive its bricks from Rome. On the shores of the Adriatic, at Pola and Zara, and in other towns of Istria and Dalmatia, the existence of a large number of bricks bearing the stamp of Rimini would tend to show that the brick trade, which still exists on

both sides of the Adriatic, can be traced back at least eighteen centuries.

But apart from the geographical information these stamped bricks afford, the inscriptions they bear throw not a little light on an ill-known state of Roman society—the education of the slaves, who though we have classic evidence proving that they were placed under schoolmasters, would seem to have little profited by this education, as the inscriptions it was their duty to stamp could only have had their letters placed upside down or transposed (as they are often found) by persons unable to read, who copied as well as they could a model under their eyes.

How these stamps and brick inscriptions were made is a point of some uncertainty. Had the ancients moulds, or did they use movable types? This latter method would suppose a great invention of the fifteenth century to have been forestalled. M. Descemet, who devotes some pages to the discussion of the question, concludes in favor of the mould, such as we see examples of in more than one national collection. The stamp was cut in relief, or incised, and then—like the butter-print of the present day—made use of. As for the character of the spelling to be met with, this would naturally arise from the want of education of the workman.

Among the various other points considered by M. Descemet, the reason why the Roman bricks bear the date of their production is not the least curious; but when Pliny's advice to the architect is remembered, only to make use of bricks when two years old—"*ædificiis nonnisi bimos probant*,"—an explanation may, perhaps, be found. A point has been omitted by M. Descemet—one to which attention is drawn in a recent able article in the *Revue des Questions Historiques*—in his neglecting to refer to the palms, pine cones, and animals so often found stamped on the Roman bricks. It is now known that with the potters whose name represented or recalled any object or animal, this object he stamped on the pottery or brick of his make. Thus, where we meet with the stamped image of a wolf we may be sure that the workman's name was Lupus.

As the title of the work shows, it is alone to the brick inscriptions relative to the *gens Domitia* that attention has been paid. Why this *gens* has been chosen the author explains. It would appear that the *gens Domitia* possessed the largest and most important of the brick manufactories of ancient Rome. Apart from this, the *gens* take no mean place in the history of Rome; in the person of the virtuous Marcus Aurelius, it ascended the imperial throne. From the brick inscriptions gathered, the wealth of the emperor would appear to have been enormous, as we learn by the large number of workshops his *gens* employed, in company with those of the *gens Aria* which he inherited through his marriage with Faustina.

The interest of this quiet and apparently little-inviting study would be thus seen to be great. Its historical value is no less appreciable. We are comparatively far from the days when the history of ancient times was merely gathered from former texts; the aid afforded by numismatics and epigraphy is largely called into requisition by the more serious modern historians. This little work of M. Descemet shows us how, even from the humble sources of the brick inscriptions, important facts may be gathered. The careful and beautifully cut Roman stone inscriptions, so easy to read, are not sufficient; the research can be carried further, as we see for instance, in the study by M. Mumont on the ceramic inscriptions of Greece, and even more strikingly in the delightful study which M. Dressel published some time since on the shattered *débris* of Monte Testaccio. M. Descemet's inquiry into the brick-marks of ancient Rome has already yielded some curious information; it is to be hoped that his success will encourage him to further study in this yet far from exhausted field of archæological research.

THE invention of binocular glasses has usually been attributed to Father de Rheita, who died at Ravenna in 1660. A printed placard has lately, however, been discovered in the Bibliotheque by Signor Govi, which indicates that the credit of the invention is due to one D. Chorez, who lived at the sign of the "Compass" on the island of Notre-Dame, and who made the "lunettes" in 1625.

AN INSTRUMENT FOR GAUGING THE FLOW OF STREAMS.

By M. DE PERRODIL.

From the "Abstracts" of the Institution of Civil Engineers.

THIS instrument, which is called a hydro-dynamometer, measures the velocity of a current by means of the torsion produced on a wire by the pressure of the water against a disc fastened to the end of the wire.

A narrow frame, resembling in form the longitudinal section of a tube terminating in a bulb at the top, is immersed vertically in the water, and turns, near its upper extremity, on a vertical pivot at the end of the horizontal bar which encircles, at its other end, an upright pole driven into the bed of the stream. A little, short, hollow cylinder, fastened to the under side of the bar exactly below the pivot, receives the end of the vertical wire, which can be secured by a screw. The wire, which is situated in the axis of the frame, passes through the center of the horizontal graduated circle, fastened, above the water-level, across the widest part of the frame, and is secured to the bottom cross-stay of the frame. A needle, fastened to the wire just above the graduated circle, serves to measure the torsion of the wire. A disc, placed in the same plane as the frame, projects from the end of a horizontal arm fastened to the bottom of the frame.

The instrument having been fixed with the disc at the desired depth, and on the up-stream side of the post, the disc assumesa position paralled to the current between the frame and the post, the needle and the frame are in the same plane, and the needle at the zero of the circle. On turning the needle by hand a torsion is produced on the wire, and the frame and disc may be thus made to assume a position perpendicular to the current. As the needle oscillates inconveniently, owing to variations in the velocity of the current, the wire is secured at the top by the screw as soon as the frame and disk are exactly perpendicular to the current, and the needle being fixed, the observer is free to note the oscillations of the graduated circle, and can read off the mean angle of torsion, which is independent of friction.

The velocity of the current is obtained by the equation $v = c\sqrt{a}$; where a is the angle of the torsion, and the value of c can be determined, either approximately from the coefficient of torsion of the material, or actually by experiment. The Author determined by experiment the value of c for the three different-sized discs he employed. The instrument was placed under one end of a small footbridge revolving round a central axis, and it moved in an annular trough, 2 feet wide, containing water. By turning the footbridge, any desired velocity could be imparted to the instrument, and the motion was so regulated as to keep the angle of torsion constant. The motion imparted to the water by the instrument passing through it was also observed, so that the actual velocity of the instrument through the water might be accurately ascertained.

A brass wire, $6\frac{1}{2}$ feet long and $\frac{1}{8}$ inch in diameter, was employed. A disc with a radius of $2\frac{1}{2}$ inches was used for velocities not exceeding 1 foot 4 inches per second, with a radius of $1\frac{1}{4}$ inch for velocities between $1\frac{1}{3}$ and $3\frac{1}{4}$ feet per second, and with a radius of $\frac{5}{8}$ inch for velocities between $3\frac{1}{4}$ and 10 feet per second. The distances in these three cases between the center of the wire and the centre of the disc were respectively 8 inches, 4 inches, and 2 inches. The Author considers Woltmann's hydrometric mill inferior to his instrument, as errors may occur in registering the number of turns of the mill, and also in marking the time, and as it has to be drawn out of the water to be read. Also the true equation for deducing the velocity from the results of observations with Woltmann's mill has not been thoroughly agreed upon, M. Chasles considering it to be an equation to a straight line, and Herr Baumgarten an equation to a parabola; but experiments conducted by the Author, and recorded in the last article, confirm the correctness of M. Chasles' view. A superiority is claimed for the instrument over Pitot's tube, on

account of its indicating the mean velocity with greater accuracy. Morever, the instrument actually employed can indicate a velocity of $\frac{3}{8}$ inch per second; whereas Woltmann's mill ceases to revolve in a current whose velocity is reduced to 4 inches per second, and a Pitot's tube is even less suited to measure accurately low velocities.—*Annales des Ponts et Chaussées.*

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS. The last issue of Transactions contains the following papers:

No. 205. The location of the Chimbote Tunnels, by O. F. Nichols.
" 206. Practical Consequences of Variation of the Wet Section of Rivers under General and Special Conditions, by Robt. E. McMather.
" 207. Wind Pressure against Bridges, by Ashbel Welch.
" 208. Cheap Transportation versus Rapid Transit and Delivery, by Martin Coryell.
" 209. The Crippling Strength of Wrought-Iron Columns, by C. L. Gates.

ENGINEERS' CLUB OF PHILADELPHIA.—The latest number of Proceedings contains:—

I. The Light-House System of the Delaware River, from the Head of the Bay to Philadelphia. By EDWARD PARRISH.
II. Rock Drills. By FRANCIS L. MILLER.
III. A Machine for the Solution of the Equation of the NTH Degree. By F. T. FREELAND.
IV. The Mexico and Vera Cruz Railroad. By COLEMAN SELLERS, JR.
V. Quantitative Determination of Combined Carbon in Cast Iron and Steel. By DAVID TOWNSEND.
VI. The Future Sewerage Requirements of the City of Philadelphia. By RUDOLPH HERING.

IRON AND STEEL NOTES.

WELDING CAST STEEL.—Two points must be taken into consideration chiefly in effecting the welding of steel: It is necessary to render the film of oxidized iron on the surfaces to be united by welding as fluid as possible, and some means must be found to restore to the steel the carbon eliminated during the process of heating to the welding temperature. According to the *Revue Industrielle*, M. Rust considers boric acid the most effectual in performing the former, and ferrocyanide of potassium in doing the latter. M. Rust considers the functions of the ferrocyanide to be also to restore to the steel nitrogen, upon which he looks as an important constituent of the metal. In 1850 a workman of Mulhouse, Alsace, sold the following receipt for a welding compound: 64 parts of borax, 20 parts of sal-ammoniac, 10 parts of ferrocyanide of potassium, and 5 parts of colophonium. M. Rust changed it as follows: 61 parts of borax, 17¼ parts of sal-ammoniac, 16¾ parts of ferrocyanide, and 5 parts of colophonium. He states that with the acid of this compound, welding may be accomplished at a yellow red, or at a temperature between the yellow red and white, and that no treatment is necessary after welding. The borax and sal-ammoniac are powdered, mixed and are slowly heated until they melt. Heating is continued until the strong odor of ammonia ceases almost entirely, a small quantity of water being added to make up for that lost by evaporation. The powdered ferrocyanide is then added, together with the colophonium, and the heating is continued until a slight smell of cyanogen is noticed. The mixture is allowed to cool by spreading it out in a thin layer. During the process given, boric acid and chloride of sodium are formed, ammonia being expelled. The same product may, therefore, be obtained by mixing 41.5 parts of boric acid, 35 parts dry chloride of sodium or salt, 15.5 to 26.7 parts of ferrocyanide of potassium, 7.6 parts of colophonium, and 3 to 5 parts of dry carbonate of soda. The only trouble with this mixture, which gives the same results, is that it decomposes easily unless it is kept in a dry place.

ENGINEERING STRUCTURES.

THE ST. GOTHARD RAILWAY.—The eighty-fourth monthly official report on the St. Gothard Tunnel works affords some interesting information as to the condition of this undertaking at the end of September last. From it we learn that as regards the main tunnel the enlargement to the full size of the arch had been carried out, through the whole distance, with the exception of a length of 131 ft. while the entire excavation had been completed for a length of 30,260 ft. The masonry of the lining of the arch was also completed for a length of 42,830 ft., and that the eastern and western sides for lengths of 32,440 ft. and 30,931 ft. respectively. Moreover, the portion of the tunnel completely finished, with waterways, refuges, etc., reached 30,504 ft., or about two-thirds of the whole length. The heading for the curved entrance tunnel at the Airolo end has also been made for a length of 233 ft., only 46 ft. remaining to be pierced. During the month of September the number of men employed on the main tunnel averaged 3051, while the total value of the works executed up to the end of the month reached 49,835,545 francs, or nearly two millions sterling. The average temperature of the air in the central part of the tunnel averaged during the month 84.2 deg. Fahr., while the maximum temperature was 89 deg. The daily consumption of oil in the tunnel averaged 1274 lbs., and of dynamite 518 lbs. As regards the railways which are being made in connection with the main tunnel, there has been executed up to the end of Sep-

tember on the line between Immensee and Fluelen 62 per cent. of the earthworks and 59 per cent. of the masonry structures; on the length between Fluelen and Goschenen, 75 and 67 per cent.; between Airolo and Biasca, 77 and 88 per cent.; between Cadenazzo and Pirro, 67 and 73 per cent.; and between Giubiasco and Lugano, 63 and 39 per cent. of the two classes of works respectively. Altogether in the five lengths of line named there had been finished an average of 72 per cent. of the earthworks and 67 per cent. of the masonry. Of the 49 tunnels on the lines of approach to the main tunnel the direction headings have been driven from end to end in the case of 34, there being included in this latter number all the tunnels on the Immensee-Fluelen section, while in the Airolo-Biasca section the headings are pierced in eight tunnels out of thirteen. The value of the works executed on the approach lines up to the end of September was, according to the prices paid to the contractors, 29,537,300 francs, or about £1,181,490. During the month of September the average number of workmen employed on these approach lines was 13,420, of which number 6,040 were engaged in the tunnels.

SIPHON OVER THE SAINT MARTIN CANAL.—In order to carry out the new drainage works of the Bercy district, it was necessary to connect the sewers, which used to discharge into the Seine, with the main sewer on the opposite side of the St. Martin canal. This was accomplished by constructing an arched siphon over the canal, which, besides possessing the interest of novelty, was not liable, like a reversed siphon going under the canal, to collect deposit in its central portion. The rise of the siphon is 26 feet 3 inches, which renders the entire exhaustion of the air more difficult to maintain, as the pressure inside the siphon, being only about one-fifth of an atmosphere, some of the gas contained in the water is set free. Tromps were adopted for removing the air and gas. Two tromps with an inlet orifice of 1 inch diameter, and an outlet of 4 inches, sufficed to make a vacuum in six minutes which one tromp was then able to maintain. In order to reduce, as far as possible, the consumption of water in working the tromps, the flow through the supply pipe is controlled by a float. The float closes a valve whenever the vacuum is complete, and opens it again as soon as a further exhaustion is needed. By thus regulating the supply, or by using a third tromp with an inlet orifice of only $\frac{5}{8}$ inch, and an outlet of 4 inches, the consumption of water was only from 10,600 to 12,300 cubic feet in twenty-four hours. The siphon has been surmounted by a chimney, raised to a height of 34½ feet above the level of the sewers, at the top of which the tromps work. As the waters of the sewer cannot possibly be drawn up to this height, the tromps are by this means removed from all danger of obstruction. One important advantage of the method adopted is, that whereas lifting pumps might be unable to discharge the waters delivered after a great rainfall, the tromps are relieved from the necessity of working as soon as the siphon discharges more than from about 40 to 50 cubic feet per second, for then the current has sufficient velocity to carry off along with it all the gases which it sets free.—*Translated papers of the institution of Civil Engineers.*

SANITARY CONDITION OF THE ST. GOTHARD TUNNEL.—Such alarming accounts have been made public of the sufferings of the men employed in this work, that, at the instance of the Italian Government, the Swiss Federal Council appointed a committee of medical men to inquire into the matter. They have reported that there is no epidemic disease as was supposed, but that the unhealthy conditions under which the labor is carried on, induce chest complaints and other internal diseases, lower the general health, and above all produce anæmia, or deficiency of red particles in the blood. The temperature rises as they penetrate into the tunnel from 12 deg. Cent. to 31 deg. Cent.; the air is loaded with aqueous vapor, carries a large proportion of carbonic acid, and is rendered additionally impure by miasma from stagnant water, smoke of lamps, and human exhalations; there is little light, the ventilation is deficient, and the men are often working in water. In winter matters become still worse, as the frost prevents the effectual working of the air pumps. From the commencement of the work up to March of this year, the deaths among the employes have been 122, of which 47 were by accidents; and in the first three months of 1880, 90 men were dismissed with anæmia. The habit so general among Continental workmen of working all seven days of the week must be counted as one of the sanitary disadvantages; for those who took days of rest were found to resist best the unhealthy influences. The company provides medical and hospital accommodation, and seems to do what is in its power for the health of its men, and the help of the families of those who succumb.

A NEW RAILWAY BRIDGE ACROSS THE TEES. For some time past the directors of the North Eastern Railway have felt that the existing railway bridge which crosses the river Tees at Stockton is not sufficient for the increasing traffic of the district. They have, therefore, recently decided to construct a new bridge, and the Tees Side Iron and Engine Works Co. [limited], Middlesbrough—formerly Messrs. Hopkins, Gilkes & Co., who built the Tay Bridge—have been entrusted with the work. The erection of this bridge will form only a part of several proposed alterations, which will also include the diversion of the existing lines of rails, and the erection of a new iron station, which will be approached from Maudale road and Stockton Bridge road. The site of the new bridge will be a little to the east of the present one, and the structure will be so erected that it will carry the diversion of the Thornton road over the railway at a point where it intersects Darlington and Cleveland streets, thus giving improved facilities to the road traffic in these two important thoroughfares. The plans for the station have not yet been matured, but they will

embody all the facilities that the public can reasonably require. The new bridge will immediately abut upon the existing one, and like it, will consist of three large water spans and one smaller land span on each side of the river; each of the large spans will be about 89 ft. 3 in. long, while the smaller ones will measure 28 ft. The level of the bridge will be 35 ft 6 in. above low water mark, and 23 ft. 6 in. above high water spring tides. The superstructure will consist of wrought iron plate web girders with wrought iron cross bars, and the rail-bearing girders are of the usual North Eastern type. The main girders measure 27 ft. 9 in. centers, 7 ft. 6 in. deep and 2 ft. 6 in. wide, while the cross girders—thirty of which are required for the bridge—are 8 ft. centers, 1 ft. 9 in. deep and 1 ft. 6 in. wide. The girders will be carried on four piers, each pier being composed of two cast-iron cylinders carrying a plate brick filling which is surmounted by a massive stone capstone. These cylinders will be sunk to a depth of 30 ft. below the bed of the river. The lower portions of the cylinders will be 10 ft. 6 in. in diameter, but about half way up it is reduced to 8 ft., and finishes with a regular tapering to 7 ft. at the top, upon which is placed a simple moulded cap. The metal will vary from 1⅛ in. at the bottom of the cylinder to 1½ in. at the top. The whole structure is characterized by a neatness and simplicity of design which makes it admirably suited for the position in which it is placed, and the traffic it is designed to carry. The scantlings in all cases are, as in all North Eastern work, amply sufficient to carry the heaviest loads that can possibly be brought upon the bridge.—*Engineer.*

THE following particulars, descriptive of the Craigentinny system of sewage disposal, were recently given in a letter by an Edinburgh firm of civilian engineers: 1. The acreage of irrigated ground at Craigentinny is 250. 2. The population draining into the stream is fully 100,000. 3. The average quantity of sewage applied per acre was till last year about 11,000 gallons daily, but the Edinburgh water supply has been increased, and probably 15,000 gallons would be more correct now. 4. The sewage is only applied to the land about once every three weeks in rotation, and it is also used during the greater portion of each winter as well as in summer. 5. The sewage is applied for several hours each time—depending on the nature of the soil—four to eight hours or so at a time. 6. The cost is infinitesimal compared with the production, two or three men doing the whole work of flooding the land. 7. The produce consists entirely of grass, which is sold in plots by public roup each spring to the cowfeeders or dairymen, and is cut and carted away by them. 8. The average produce is 30 to 40 tons per acre, and the price per acre varies from about £25 to £45. 9. A great portion of the now irrigated meadows formerly consisted of stretches of land worth perhaps 10s. per acre. 10. It is an error to assume, as many seem to have done in England, that only sandy stretches are suitable for irrigation; as a rule, the better the soil the better the result obtained. 11. The notion of the irrigated meadows creating any nuisance of consequence, or being a source of any specific disease, has long been abandoned as untenable by our most distinguished medical men who have considered the subject, and by Dr. Littlejohn, medical officer of health for Edinburgh. Irrigation, like everything else, is a subject that requires careful consideration in each case, combined with some practical knowledge and experience, and it is probably the want of such caution that has caused so many disappointments and failures in dealing with the question.—*Engineer.*

RAILWAY NOTES.

WRITING on railway accidents in Germany, the Berlin correspondent of the *Daily News* draws attention to the condition of the German railways under State management. He says: "Another serious railway accident has occurred on the Belgian-German Frontier, near Herbesthal, on the direct Cologne and London line. A collision took place between a passenger train and a goods train with great violence. Eight persons were killed on the spot, and a large number severely injured. The frequency of serious accidents in Belgium, and especially in Germany, is at last beginning to attract attention here; and the English traveling public should not forget that the lines they mostly use are at present the most dangerous. On returning from Cologne last week, I was lucky enough to miss my train to Berlin, which I heard on the following day had been smashed up near Dortmund, with a large number of killed and wounded, Now that the Prussian railways have become state property, the government adopts the principle of economy in every branch of the railway service. For instance, the number of the line inspectors has been reduced to a minimum, one chief inspector being made responsible for so many hundred miles of line, over which it is practically impossible to give the necessary supervision under only one head. Secondly, when a railway accident does occur, such secrecy is observed that a long time elapses before the public are made aware of the exact number of dead or injured, and the matter is hushed up as soon as possible; and the press having no means of obtaining a true account, pays exceedingly little attention to these terrible disasters—that is to say, unless they happen in England, and then as much is made of them as possible. For the past fortnight not one single day has elapsed but an accident more or less serious has been curtly reported in the German papers as happening on German railways. I hear that the Progressists are going to interpellate the Prussian Parliament concerning the new state management of the railways. One thing certainly is striking, that under the new *regime* pointsmen only get 1s. 6d. to 1. 9d. per day."

FUNICULAR RAILWAY.—*La Nature* gives an interesting account of the funicular railway lately brought into use at the Giessbach, for conveying passengers between the pier and

the hotel on the mountain side. This line is worked on the same principle as the convenient trams at Scarborough, by which people are carried up and down the cliff, i. e., two carriages are connected by a rope, so that one ascends while the other descends; the excess of weight being supplied to the descending carriage in the form of water. At the Giessbach, the line is a single one, except in a small portion at the middle, where the two carriages pass each other. This crossing is effected automatically. Six wheels of one carriage having all their flanges exterior, whilst those of the other have theirs interior, the rails being adapted in accordance, to give the desired result. A wagon for luggage is worked without the cable, by means of a toothed wheel catching in a rack-rail; this is driven by four men. The carriages have a pinion on the front axle, catching in the rack-rail; also brakes, and a catch which is raised by a counter weight while the cable is tense, but acts in case of rupture. The water is from a reservoir, supplied by the Giessbach fall. This railway is 346 meters long, and the slope in some parts is as much as 28ctm. per meter. A rising carriage filled with (40) passengers may weigh 9,500kg.; and the excess of weight for the other carriage is 1,300kg. The velocity is about 1 meter per second, so it takes 346 seconds (about 6 minutes) to make the journey.

A LARGE meeting at Victoria (Vancouver's Island) has passed a resolution declaring that separation from the Dominion would be the best course if the government of the latter fails to carry out its obligations with regard to the Pacific Railway.

A TRIAL was made in Berlin, in November, in the presence of Count Moltke, of a new traction engine, adapted to military purposes. This engine drew five heavy guns of 15 centimeter bore, through the streets for over two hours, at the cost of two marks an hour. The trial was considered by Count Moltke and the staff very satisfactory. Probably, the *Daily News* Berlin correspondent says, the traction engine will become an institution in the German army.

ACCORDING to intelligence from Paris in the *Presse*, which is confirmed from other quarters, the project of direct railway communication with Constantinople, *via* Roumania and Bulgaria, has been taken up very seriously. The report of M. de Serres, the engineer-in-chief of the Austrian Staatsbahn, who was sent last summer at the instance of the late M. Isaac Pereire, the president of the Paris Committee of the Austrian Staatsbahn, to open negotiations with the Roumanian and Bulgarian governments, convinced those who had taken up the idea, and also the late M. Isaac Pereire, of the feasibility of the scheme. It seems that a separate company, mostly composed of French capitalists, is to take in hand the scheme, and that the necessary capital needed has already been secured by subscription—nay more, for whereas the estimates show a necessity for a capital of only 60,000,000f., the company is to be formed with a capital of 100,000,000f. This has given rise to the supposition that there is a design of eventually extending the network in Bulgaria. The negotiations with the Roumanian and Bulgarian governments are said to be already so far advanced, that in both legislatures the law authorizing the company to build, and insuring it a handsome guarantee per mileage, is to be brought in shortly, so that the work may begin next spring. The anticipation may, perhaps, not be realized, but there seems little doubt that the scheme of this railway connection is now seriously entertained.

SPEAKING of a train which was blown over a precipice on the Wellington and Graytown Railway, New Zealand, on the 12th September last, the following particulars are given in the Melbourne *Argus*, and are more definite than any previous account which has reached us: The train was composed of—first, two composite carriages, then the ordinary guard's brake-van, then the Fell engine, then two luggage vans filled with furniture, produce and sundry goods, and, last, the incline brake van, with a guard in it. The wind on the plain was not stronger than usual, there being only an ordinary breeze; but as the train went up the mountain's side very strong gusts were felt at different spots, where the configuration of the hills allowed them to strike the train. Nothing, however, happened, and the train went on all right through the first tunnel, and had emerged through a cutting within fifty or sixty yards of the second or middle tunnel. This spot is called Siberia, on account of the violent and piercing blasts that sweep down the hollow of the hill. The line runs along a sort of embankment, formed from the stuff taken out in making the tunnel; but on the right side the hollow formed by the embankment side and the adjacent hill is only a few feet deep, while on the other side there is a steep declivity of over 100 feet, running down to a creek. The train was going slowly along this embankment, when the wind, catching it broadside with enormous force, without an instant's warning, lifted the two front carriages and van clean off the rails, and swung them around and down the deep embankment, one hanging to the other. The carriages were swung round farther than what would have been at right-angles with the rails, and as they were then motionless, formed an acute angle with the engine. The first carriage as it swung over went on its side, and the shock started the body from the bed and wheels. The body rolled away down, breaking to pieces as it went, and the wind carried the pieces in every direction. The second carriage was turned square on its side, and so remained, all the windows, of course, being shattered in. The van was partly thrown over, and rested obliquely, two wheels being sunk in the embankment, and the other two in the air. The engine, the two goods vans, and the other brake retained their position on the rails.

ORDNANCE AND NAVAL.

THE INCREASING POWER OF GUNS.—A remarkable result has recently been achieved by Sir W. Armstrong and Co. in the production of a gun, weighing 95 cwt., discharging a projectile weighing 120 lbs., with a velocity of 2064ft. per second—that is to say, having 3545 foot-tons stored-up energy, or 746.3 foot-tons per ton weight of guns. The gun is an experimental one, and we should suppose that such a result must be exceptional, being, of course, very extraordinary, and a stride in advance even of the 613.5 foot-tons per ton of gun obtained by the 6in. Armstrong, reported in *The Engineer* of November 5th. At present we speak of this as an abnormal individual result. How much the gun is able to bear as a regular service round we cannot say. The fact, of course, indicates something unprecedented. In recording this we would take the opportunity of correcting an expression which may mislead a reader in the article of November 5th above referred to. We there spoke of a delicate point, namely, the question of priority of Armstrong 6in. and Krupp's 15-centimeter guns, whose results we compared together. Speaking from the reports of each lying before us, we considered that the two pieces dated from about the same time. In doing so we unconsciously did injustice to the Armstrong gun; for while Krupp's pamphlets, issued at the Meppen trials, as we understand them, contain the records obtained of their earliest private trials, which took place on December 17th, 1878, the report of the Armstrong results dealt only with a certain series of Government trials. Previous to this, we have now ascertained, a Government trial had taken place on May 2nd, 1878, and private trials as early as December, 1877. This, it will be seen, argues a year precedence for Armstrong as compared with Krupp, which in a question of this kind may mean everything, and should certainly be clearly stated.

ROBERTS'S RANGE FINDER AT WOOLWICH. Captain Roberts, R.A., recently described a range finder designed by himself to an Artillery audience, General Turner, C.B., the commandant of the garrison, and his staff being present. This range finder mainly consists of a telescope with large field, such as it is proposed to issue to field batteries, mounted on a tripod stand, with cross lines and prism. The glass is directed at the object, and the prism then applied so as to cause the line of vision to be deflected at a right angle to a staff carried on the shoulder of an assistant, and correctly placed by means of a second small glass and optical square. Numbers are read off, for the use of which the range can be read off a slide rule. The operation is a rapid one for intelligent men. It would not here be fair to compare it with Watkins' or Nolan's systems. It is, at all events, a matter for congratulation that so much interest should be displayed in range finding by combatant officers. The best conceivable range finder might be introduced to the committtee, without after all achieving much, unless an efficient system of instruction is set on foot by the Adjutant-General.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

MONTHLY Report of the Meteorological Bureau for October.

Papers of the Engineer Department, U. S. Army, contains: Hollow Brick Foundations, Arches in Masonry Bridges. By Wm. H. Bixby, Lieutenant of Engineers, Washington: Government Printing Office.

Les Tarifs des Chemins de Fer, par N. C. Leon Augoc. Paris; Dunod.

MODERN ARCHITECTURAL DESIGNS AND DETAILS.—Nos. II. and III. New York: Bicknell & Comstock. Price, $1.00 each.

This excellent work maintains the excellent character exhibited in the first issue. The style of the designs and the finish in execution make this work invaluble to the young architect.

Suburban cottages in wood form the illustrated subjects of the two numbers before us. The minuteness of detail leaves nothing to be desired in the way of completeness.

THE CURRENT GOLD AND SILVER COINS OF ALL NATIONS. By IVAN C. MICHELS. Ph. D., M. A. Philadelphia: R. S. Menarnin. For sale by D. Van Nostrand. Price, $3.00.

This is an illustrated quarto, giving by pictorial illustration and tables all that can be desired in the way of information about gold and and silver coins.

Weights, fineness and intrinsic values are reduced to United States standard.

The entire history of United States coinage is given from 1792 to the present time.

To facilitate the use of this work a complete alphabetical index is added.

A PHYSICAL TREATISE ON ELECTRICITY AND MAGNETISM. By J. E. H. GORDON, B. A. New York: 1880. Price, $7.00.

In the present time of rapid progress in practical electrical science, every new treatise is scanned in expectation that it contains something new in the way of exposition of the later recognised phenomena. The great need has, however, been of late a treatise that should discuss collectively the phenomena of electricity and magnetism from the physical standpoint only, as distinguished from the mathematical, and should, moreover, regard the work of the practical electricians as something within the province of accepted theories.

The present work seems to accomplish this. Under the head of Electro Statics, all the ordinary experiments of the lecture room in frictional electricity are discussed, together with all the elaborate devices of the philosophers used in their researches. Under magnetism all that relates to magnets, terrestrial magnetism and the delicate methods of measuring and recording the latter.

Electro kinetics covers a wider field; and be-

ginning with battery cells the author passes to the consideration of the units of measure and their application in practical uses. Electro magnetism and magneto electricity are discussed under this heading; also the various phenomena produced by the induction coil, secondary batteries and the laws of electrolysis.

Electro-optics forms part four and closes the work.

Throughout the treatise the works of the leading philosophers are described and their opinions quoted. All varieties of instruments of research are fully illustrated and their objects and uses described.

This work is undoubtedly the most complete compendium of electrical science in the English language.

PRACTICAL BLOWPIPE ASSAYING. By GEO. ATTWOOD, A. I. C. E. New York; D. Van Nostrand. Price, $2.00.

Quantitative assaying with the mouth blowpipe is a difficult process. Plattner's voluminous treatise has been followed by the few who have acquired enough proficiency to feel confidence in their results, but even with the most enthusiastic students, the success under this guidance is so out of proportion to that attained with similar effort in *qualitative* determinations that but few have patience to acquire any considerable skill in determiningthe quantities in their essay.

The present treatise, recognizing fully the difficulties of the process, proceeds in the most concise way to inspire confidence in the learner and lead him to adopt sure and available methods to insure success.

First, the elementary bodies are mentioned and directions given for their determination separately. This, with the description of the apparatus and reagents constitute the first two parts of the work.

Part III is devoted to the assaying of silver, gold, mercury, copper, lead, bismuth, tin, iron, nickle, cobalt and coal.

The author suggests a useful check in the way of synthetic assays, which consists in the preparation of weighed quantities of the pure element or elements to be determined, mixed with materials resembling as nearly as possible the ore to be determined. Any loss of the element sought in the artificial mixture serves as a guide to correct the regular assay.

Part IV. contains useful tables. The illustrations and typography are excellent.

The book is designedly of convenient size for carrying while prospecting.

A TREATISE ON METEOROLOGICAL INSTRUMENTS. By Negretti & Zambra: London. For sale by D. Van Nostrand. Price, $2.00.

The fame so justly earned by these makers of scientific apparatus gives weight to their statements regarding the instruments employed in any department of scientific labor.

For the proper care and use of meteorological instruments, an instruction book is indispensable, such a treatise is provided with this minute description of the construction of the instruments.

Five chapters are devoted to barometers alone, five chapters to thermometers; then follow chapters on hygrometers, rain-gauges, anemometers, electroscopes and ozonometers.

Tables for barometers and boiling-point thermometers are added.

The text is embellished with ninety-eight wood cuts.

NEGRETTI & ZAMBRA'S DESCRIPTIVE CATALOGUE OF PHILOSOPHICAL INSTRUMENTS. Negretti & Zambra: London. For sale by D. Van Nostrand. Price, $2.50.

The peculiarity of this catalogue is that the construction of the apparatus is so far described, and the range of subjects so comprehensive, that the so-called catalogue becomes an exceedingly convenient encyclopedia.

An occasional essay on the progress in some department of scientific research increases the usefulness of this handy volume.

There are several hundred illustrations distributed through 540 pages of royal octavo text.

MISCELLANEOUS.

LEHMANN'S HOT-AIR ENGINE.—The risks and trouble incidental to the application of steam to engines of small power are now generally recognized. A steam boiler must always have close and personal attention by a fairly skilled or practiced hand. These needs for attention and possible dangers, are avoided by the use of heated air as a source of power instead of steam. The elasticity and expansion of air heated to 600° or 800° Fahrenheit is sufficient to develop an appreciable pressure, and thus to enable a small engine to be driven up to a moderate power, such as that of a half or one horse. Larger powers may of course be obtained, but will require larger diameters of cylinders, as the effective pressure to be obtained by the expansion of the hot air is not capable of any great increase. The engine we illustrate herewith is Lehmann's patent, manufactured by Messrs. W. H. Bailey & Co., of Salford, Manchester, and is a very well designed and effective specimen of its class. The construction of the engine is horizontal, the heating apparatus consisting of a brick-built furnace. In this is fitted a steel air heater which may be raised to a dull red heat. The working cylinder is fixed outside the furnace, and its front part is jacketed by water jacketing. A cold chamber is thus provided in which the expanded air is condensed and contracted to its original volume. The working piston is an open plunger, which is made air tight by a cup-leather packing. As this packing is fixed in the cold portion of the engine it does not suffer from the heat, and will last a long time without attention, whilst at the same time it forms a tight and frictionless method of packing. It has always been difficult to apply a piston packing in these engines which will stand the heat of the air. Any class of packing, which must be packed by a gland, would also offer on a large plunger far too great a proportion of frictional resistance in engines of such small power as those worked by hot

air. The working plunger operates directly upon a rocking lever, to the end of which is attached the connecting rod driving a crank and fly-wheel carried in bearings on the top of the cylinder. A circulating pump to supply the water jacket is fixed on the bed-plate, and driven from a rocking bar by a return crank and connecting rod. The hot air is first expanded in the hot chamber which causes the piston to drive forward, the air then escapes at the end of the stroke, and by passing through a cold chamber is reduced to its former bulk, and may be thus returned to the hot chamber without much back pressure on the piston or plunger. The same volume of air is thus used continuously, first being expanded and then contracted for the working and back strokes respectively. No foul heated air is thus discharged by the engine, to which there is no exhaust.

It is somewhat surprising to note the immense rapidity with which the air can absorb heat and give it up again, as we find that as many as 1000 revolutions per minute have been obtained from the smaller sizes. This power of speed will no doubt depend upon the skillful arrangement and extent of surface of the heating and cooling chambers. This engine appears to be very economical, as the makers state that a 1-horse engine will run for twelve hours at a consumption of 50 lbs. of coke. A great advantage also is that such an engine may be safely left to run itself down, since no damage can ensue to it, as it will only stop when the fire gets to low. In this way Lehmann's engine may be left to run all night without any attendance or the fear of a mishap. When applied to farm or domestic purposes the engine need cost little or nothing to work, as the heat of the stove may be utilized for warming purposes, and even the hot water from the cooling jacket would be found serviceable. A pumping apparatus may be attached to the bed plate of the engine so as to form a compact and serviceable pumping engine.

SOMETIME ago the executive committee of the Citizens' Association of Chicago appointed a sub-committee to consider the subject of house drainage. That committee consisted of Frederick Baumann, James R. Willett and Bryan Lathrop. After considerable investigation and prolonged deliberation the committee has embodied its ideas in a report, of which the following is a brief summary of the recommendations made:

1. Concrete the ground under the entire building.

2. Ventilate the main sewers by a perforated cover on every man-hole.

3. Every house to have a cast iron soil pipe, not less than four inches in diameter and one-quarter inch in thickness, tarred inside and outside, running from sewer to roof, without a trap, accessible for inspection throughout its entire length, and with as great a fall as possible; the openings for waste and soil pipes in the house walls to be larger than the pipes, to allow for settling.

4. Every sink, wash basin, bath tub and water closet (except the "trapless" closets) to be trapped.

5. Every trap to be ventilated from its highest point into a pipe running out above the roof, and disconnected from the soil pipe.

6. Joints in iron pipes to be leaded and caulked to rust joints. Joints between iron and lead pipes to be made with tinned iron or brass ferules, soldered.

7. Catch-basins to be built outside of the house wherever possible, and ventilated by a special pipe.

8, Water closets to connect with the outer air by a window or light shaft, and to have a ventilating flue.

9. Avoid pan-closets, and use hopper or improved closets.

10. On the upper floor each water closet to be flushed from a separate tank through a pipe not less than one and one-quarter inch in diameter.

11. Catch-basins to be periodically cleaned by the city authorities.

Sanitary Legislation.—It is the custom of all cities to control, by municipal ordinance and by supervision, matters affecting the public health. Nothing can more properly come within the scope of municipal legislation than measures regulating house drainage, in order to prevent, as far as possible, the generation and spread of infectious diseases. It is obviously necessary to make the precautions obligatory upon all the people, as their efficacy depends on the general use of them, and it is to the interest of all that they should be universally adopted. Your committee, therefore, recommend that an ordinance be passed by the common council of Chicago embodying the most important of the foregoing recommendations, as follows:

1. That every house which shall be connected with the city sewers, after this ordinance goes into effect, shall have a continuous pipe of not less than four inches inside diameter, running from the street sewer to at least two feet above the roof of the house, without any trap throughout its entire length; the opening at the house wall to be larger than the soil pipe, to allow for settling.

[NOTE.—As there may be some who will prefer to use a trap on the house drain or soil pipe, this vent pipe may in that case be made independent of the house drainage, and be carried through the house without any opening into it.]

2. Every sink, basin, bath tub and water closet (except "trapless" closets) to be trapped, and every trap to have a vent pipe from its highest point.

3. Joints in iron pipes to be leaded and caulked or rust joints. Joints between iron and lead pipe to be made with tinned iron or brass ferules, soldered.

4. Soil pipes to be of iron.

5. All water closets to be connected with the outer air by a window and ventilating flue or a light shaft.

6. Sanitary inspectors to be appointed, under the direction of the health commissioners, to enforce the observance of the foregoing provisions.

THE EARTH'S MAGNETISM.—The great physical problem of terrestrial magnetism has engaged the attention of numerous physicists lately, and it is well known that several ingenious solutions of it have been propounded. Professors Ayrton and Perry, for example, conceived the happy thought that the earth was charged with static electricity, which being carried round on the surface by the diurnal rotation, acted like a circulating current and magnetized the core. A severe blow was dealt to this hypothesis, however, by the mathematical criticism of Professor Rowland, who pointed out that the surface charge required was competent to send a spark from earth to moon. A theory based upon the existence of electric currents flowing in the atmosphere around the earth was promulgated later; and now we have another supposition, which has a better claim to serious attention than any of the rest because it is supported by direct experiment. Starting from the idea of M. Edlund that an electric current is really an ether current flowing in the circuit, and that electrostatic effects are due to rarefactions and condensations of the ether, M. Selim Lemström considered that he might produce this ether current by mechanical action. He, therefore, made a paper tube having two concentric walls and mounted on an axle. A core of soft iron was placed within the tube, and on rotating the latter the core was found to be magnetic, as demonstrated by two fine astatic needles. Reversing the rotation, reversed the magnetic poles; and M. Lemström concludes that the relative motion of the ether in the revolving tube and the stationary core was the cause of the polarity. It follows that if the tube be stationary and the core revolved a similar effect will be produced; and hence if a magnetic body like the earth be rapidly rotated round its axis in an insulating medium like the air, it will exhibit magnatism. Pursuing this idea into mathematics M. Lemström arrives at an expression for the magnetic moment of the which agrees very well with the formula of Gauss.

AN ELECTRO-DYNAMIC PARADOX.—Dynamo-electric machines like M. Gramme's are reversible, and can either generate a current from mechanical work or from a current produce mechanical work. Under the same conditions continuous current magneto-electric machines do the same thing. But if the current from a dynamo-electric machine is sent into a magneto-electric machine a very strange effect results. This effect is signalled by M. Gérard-Lescuyer, who calls it an electro-dynamic paradox. Soon as the circuit is closed the magneto-electric machine begins to move, and tends to acquire a speed proportional to the intensity of the current actuating it. But suddenly it slackens speed, stops, and then begins to rotate in the contrary direction, only to arrest itself anew and begin again as before. In a word, it exhibits a regular alternative motion, lasting as long as the current which actuates it. What, asks M. Lescuyer, is the cause of this phenomenon? Evidently the motive current changes its direction; and a galvanometer introduced into the circuit proves it. But how does it produce itself when the speed of the prime mover, be it steam or other engine, does not vary? The effect must be due to an exterior cause reversing the polarity of the inductors of the dynamo-electric generator so as to cause it to give birth to a reversed current. This reversal is proved by placing a compass near the inductors, and this reversal keeps time with the reversal of the current, as shown by the galvanometer in circuit with the machines. Let us suppose that the magneto-electric receiver has periodic increases of velocity. These will give rise to a current of its own in the magneto-electric machine, which will traverse the dynamo-electric machine, and as it will be a contrary current to that coming from the latter it will tend to reverse the polarity of the inductors of the dynamo machine. Hence a reverse current will proceed from the latter. To test this hypothesis it is sufficient to prevent the increase of the velocity in the magneto-electric receiver by means of a brake. As soon as the brake is put in play the paradoxical effect vanishes, and the receiver goes uniformly in the same direction, whilst the galvanometer and compass are unaffected. The experiment is well shown by a Siemens dynamo-electric continuous current machine for generator, and a small laboratory Gramme with ordinary permanent magnets, as constructed by M. Breguet, for receiver.—*The Electrician.*

ASTRONOMY IN ROCHESTER.—The new Warner Observatory which is being erected at Rochester, N. Y., is attracting much attention in social and literary as well as scientific circles. The new telescope will be twenty two feet in length, and its lens sixteen inches in diameter, thus making it third in size of any instrument heretofore manufactured, while the dome of the Observatory is to have some new appliances for specially observing certain portions of the heavens. It is to be the finest private observatory in the world, and has been heavily endowed by Mr. H. H. Warner. Professor Swift has labored under numerous disadvantages in the past, and the new comet which he recently found was in spite of many obstacles; but as the new institution is to be specially devoted to discoveries there are good reasons to expect very many scientific revelations in the near future from the Warner Observatory at Rochester.

A MAN on board the Livadia was asked on Saturday evening last to support an electric lamp temporarily, while arrangements were being completed for hoisting it to its position, and by mistake placed his hand in such a position as to divert the current from the candle through his body. He was killed instantaneously.

THE coal beds on the Souris River, Manitoba, a southern affluent of the Assiniboine, have, it is said, turned out rich, and will be developed during the coming winter. The Souris being only navigable in the spring time, it is proposed to float the coal down in flat-bottom scows.